USER' S MANUAL

HelixPile software program (Version 2012)

Version 1.0

Issued: 12-March-2012

Deep Excavation LLC

www.deepexcavation.com

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Chapter 1: Introduction to HelixPile

1.1 About HelixPile (Helical Pile Engineering Program)

HelixPile 2012 is a user friendly, modern and powerful software program for the design of helical piles. HelixPile allows the user to include an unlimited number of stage conditions and soil profiles. HelixPile incorporates the latest recommendations and reports the controlling design design conditions.

1.2 Software Compatibility & Installation

HelixPile is compatible with Windows (OS) XP, Vista and 7. A minimum of 120 Mb must be available on your hard disk.

1.3 Support & Technical Assistance

Support and technical assistance for *HelixPile* is offered through our web site at:

www.deepexcavation.com

1.4 Acknowledgements

Deep Excavation LLC would like to acknowledge the contribution of Howard Perko from Magnum Piering, who has been extremely helpful when the program authors had questions regarding helical pile design.

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1.5 Activating the software

In order to activate the license, the following steps are required;

1) Download and install the software.
2) Keep the SHIFT key pressed (or CAPS locked) and start HelixPile 2012
3) The activation window should appear (Figure 1.5.1).
4) E-mail us the SITE and MID codes that appear in this window (see Figure 1.5.1).
5) We will then e-mail back the user's activation code
6) Restart the program (with CAPS locked) and enter the activation code in the Deep-Paratie activation window (select the option Unlock application) (Figure 1.5.2).
(please pay attention not to paste the activation code with any additional space characters)
7) Press Continue.

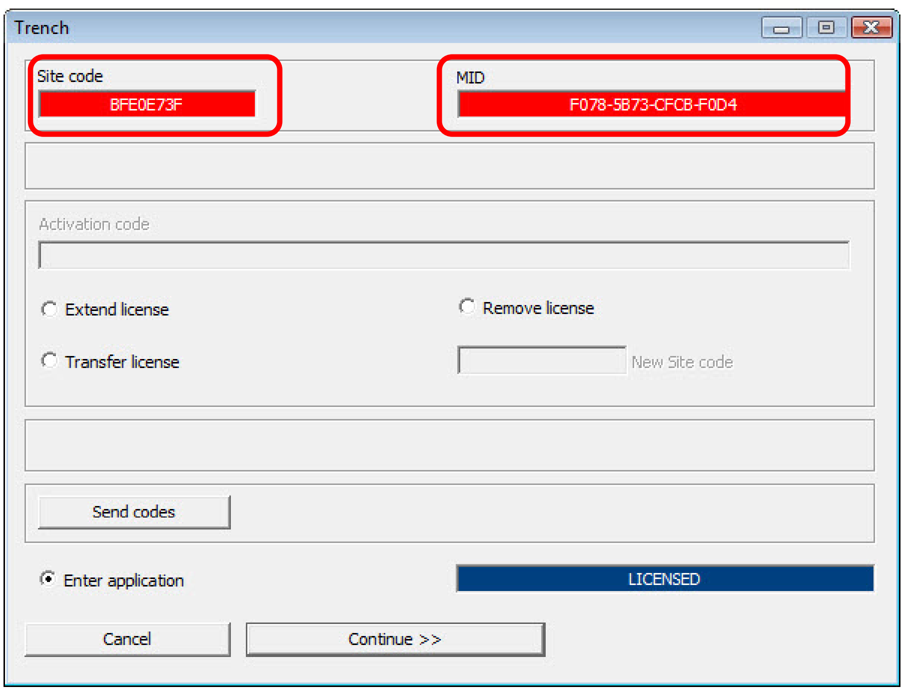


Figure 1.5.1: The HelixPile activation window – SITE and MID codes**.**

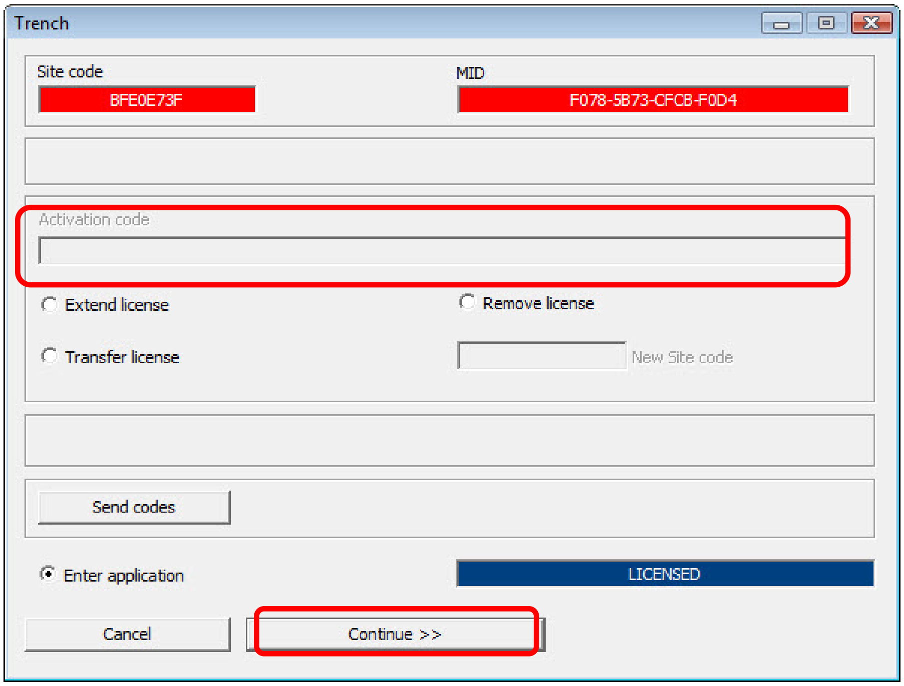


Figure 1.5.2: The activation code area**.**

Chapter 2: Using HelixPile

2.1 Using HelixPile

HelixPile is a user-friendly software program that includes powerful features and versatile options for helical pile design. HelixPile offers the ability to work with many design sections of a model that can represent various conditions. In a sense, a design section is a design scenario. This way, multiple conditions can be examined simultaneously. The main interface is shown in Figure 2.1.1. The general philosophy in creating a model in HelixPile is:

1) Specify the global coordinates.

2) Specify the soil types and properties.

3) Specify the layers and stratigraphy.

4) Create a generalized water table.

5) Specify the pile properties (depth, x-coordinate, number and dimensions of plates).

6) Specify different stages

7) Specify HelixPile analysis combinations and standards.

8) Analyze the project.

The general tabs that appear on the top of the program have the following functions.

1. General: This tab includes general information about the project, model limits, general settings and the HelixPile analysis options.

2. Properties: This tab contains various information about Borings and soils.

3. Model: Here we can define borings, surface and water elevations and add or delete stages.

4. Settings: Here we can modify the general program settings (units, language options etc).

5. Design: In this tab we can define code options and several safety factors.

6. Results: In this tab we can select to present results directly to the screen after the analysis is performed.

7. Report: In this tab we can select options for generating output reports, or viewing calculation progress files.

8. View: In this tab we can modify various view options or generate a top view of the model.

9. <u>Help:</u> This tab provides links to help and terms of use.

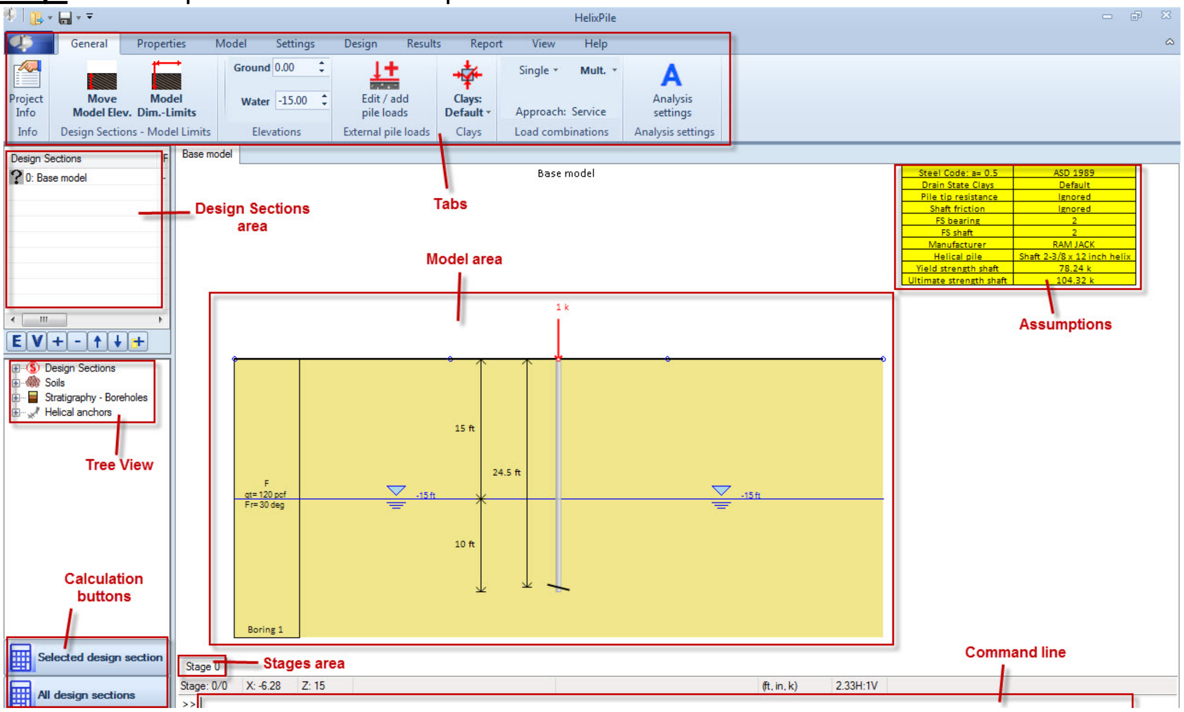
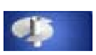


Figure 2.1.1: General HelixPile 2012 Interface

2.2.1 HelixPile Toolbar Functions

The following section provides a detailed list of all toolbar functions. The first tab group to encounter contains the following options:

- **Start button** 

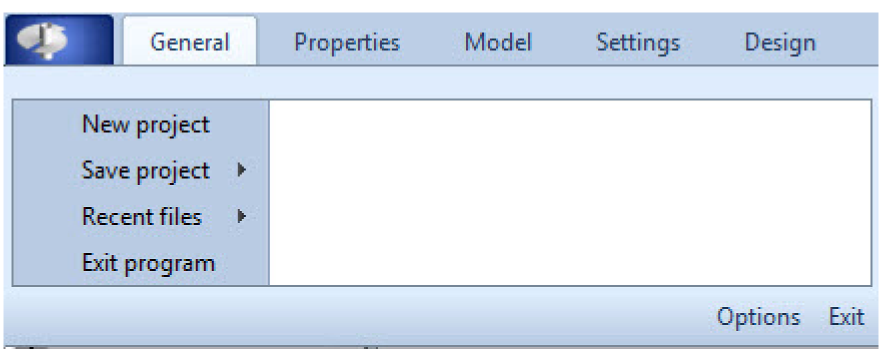


Figure 2.2.1: Main button

This window provides the following options:

- Create a new project
- Save a project to a folder
- See and choose to open recent files
- Exit the program

A horizontal toolbar available right under the design section list allows the user to edit section names, add new design sections etc (Figure 2.2.2). The icons are presented and described in the table below:

Tool	Description
	Edit the name of the selected design section
	Generate a new view of the current design section
	Add a new design section
	Delete design section
	Move design section up on the list
	Move design section down on the list
	Add a new design section (empty – including only stage 0)

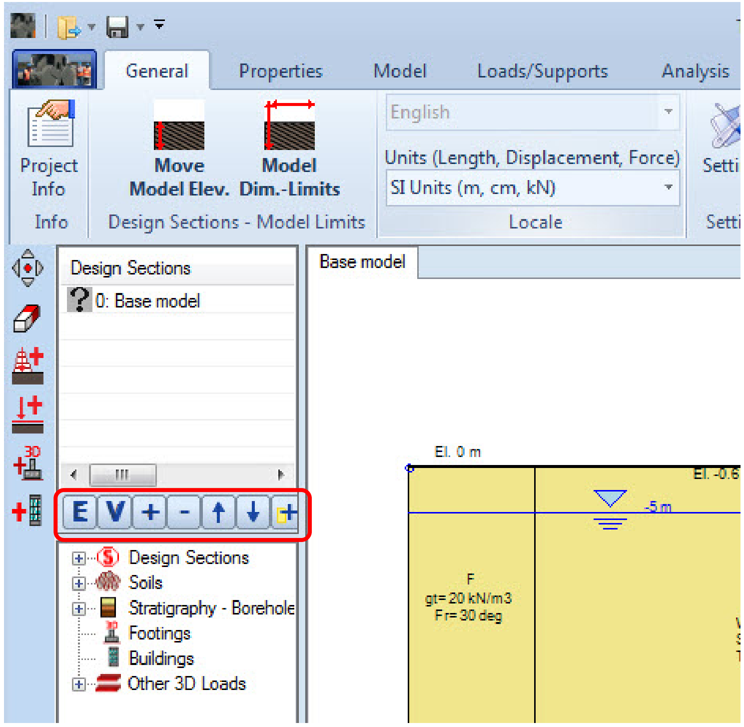
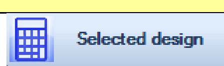


Figure 2.2.2: Design section toolbar.

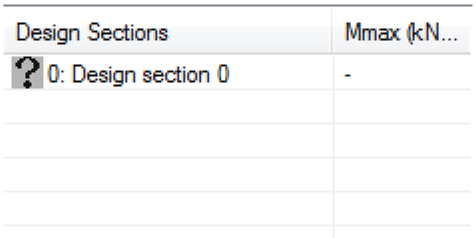
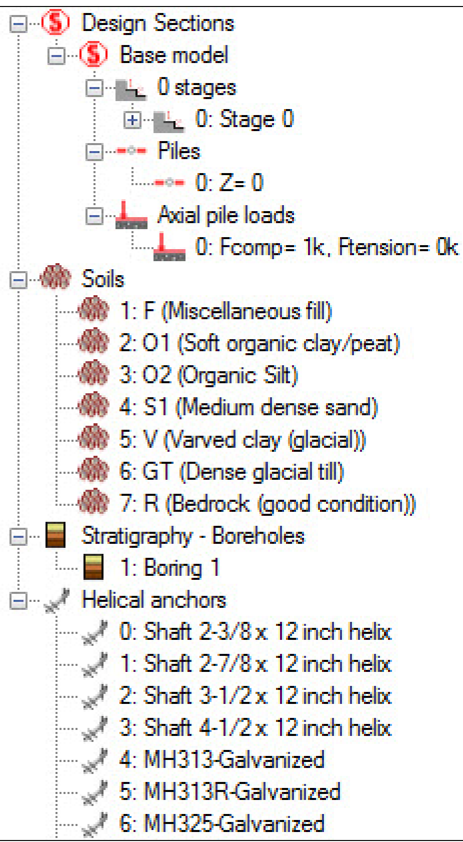
Two calculation buttons are available on the bottom left corner of the program. By pressing either of these buttons the program will analyze the desired design section and determine the estimated pile capacity.

Figure 2.2.3: Calculate tools

Tool	Description
	Calculate the selected design section
	Calculate all design sections

2.2.2 Design Section List, and Project Tree View

HelixPile includes a table on the left that displays all available design sections and a tree-style project view. The tree view enables the user to quickly access vital project data, as well as visualize crucial project settings. The next table briefly describes the functionality of the design section list, and tree view items.

	Selects current design section, shows available design sections.
	Shows available design sections Pile loads (right click to add or erase) Piles (right click to add or erase)
	Available soil types (by clicking the user can select which soil's properties to modify)
	Available boreholes (by clicking the user can select which borehole's properties to modify)
	Helical anchors (by clicking the user can select to change the properties of the helical anchors)

2.3 General menu

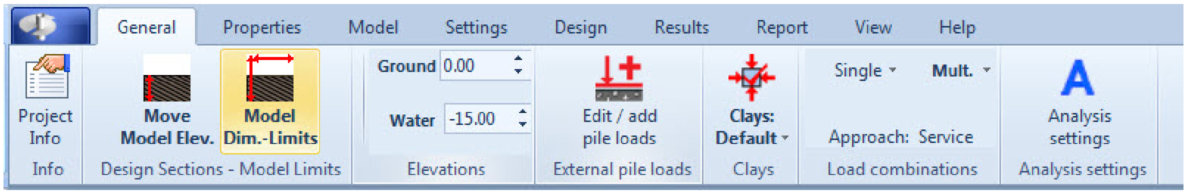
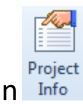


Figure 2.3.1: Project info, model limits, ground and water elevations, load and clay settings, load combinations, and analysis settings.

- **Project Info:** by pressing the button 

, we can change the project, file, company and engineer name

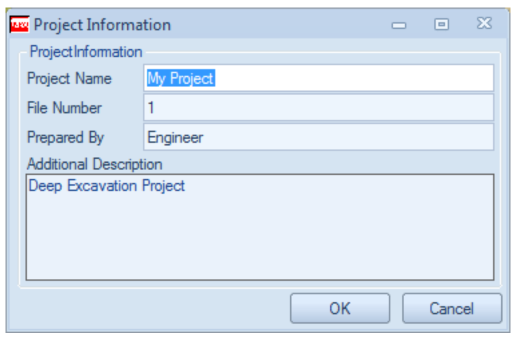
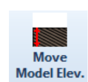


Figure 2.3.2: Project information dialog.

- **Move model elevation:** by pressing the button 

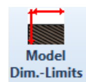
, we can change the model elevation by entering a new top of wall elevation.

Figure 2.3.3: Model Elevation dialog.

The user can choose the objects to be affected by the change in elevation. These are:

The design section coordinates
Soil layers elevation (of current borehole)
Soil layer elevations for boreholes
Surface elevations
Pile top elevations
Surcharge elevations
Elevations of all footings and buildings

The top of the pile is used as the point of reference for changing all elevations.

- **Model Dimension - Limits:** by pressing the button 

, we can change the design section name and the model Limits to create a better view of the model.

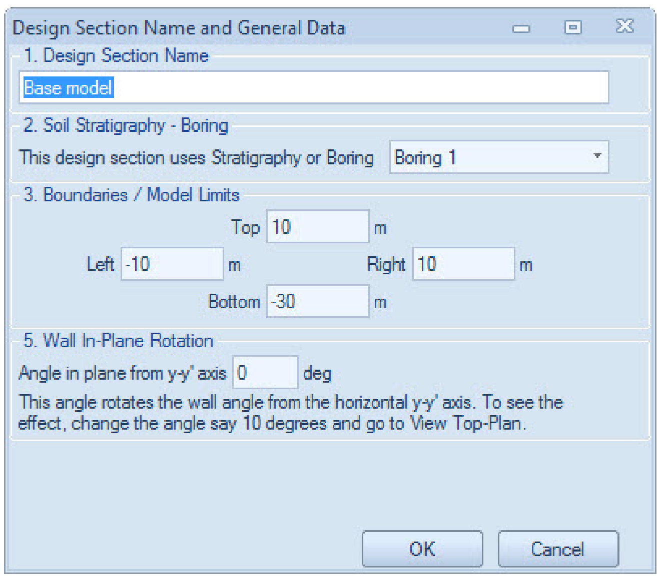


Figure 2.3.4: Model Dimension – Limits dialog.

This dialog includes the following options:

- The design section name.
- The model limits. Here we can define the top, bottom, left and right limits of the model. These are absolute coordinates.
- Angle in plane from y-y' axis.

- **Elevations:** Change the general ground elevation and define the water table.

- **External pile loads:** by pressing the button 

, the "Loads on Pile" dialog appears.

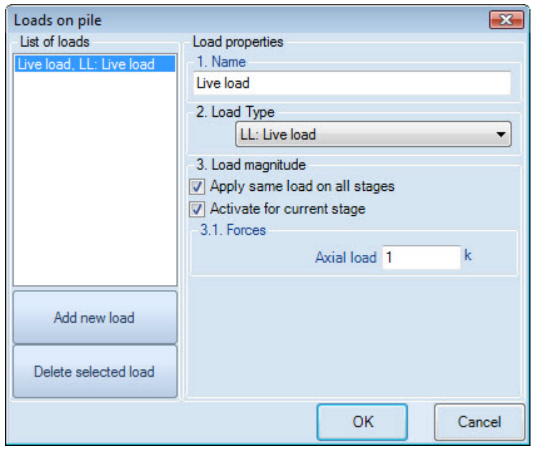


Figure 2.3.5: Loads on Pile dialog

In this dialog we can:

- Add or remove a pile load.

- Specify the load type as presented in the figure below

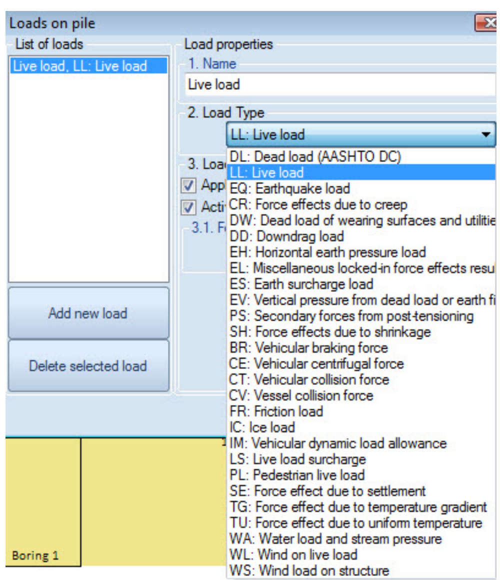


Figure 2.3.6: Settings – Soil/Properties Tab.

We can choose among the following options:

DL	Dead load (AASHTO DC)
LL	Live load
EQ	Earthquake load
CR	Force effects due to creep
DW	Dead load of wearing surfaces and utilities
DD	Downdrag load
EH	Horizontal earth pressure load
EL	Miscellaneous locked-in force effect results
ES	Earth surcharge load
EV	Vertical pressure from dead load of earth fill
PS	Secondary forces from post-tensioning
SH	Force effects due to shrinkage
BR	Vehicular braking force
CE	Vehicular centrifugal force
CT	Vehicular collision force
CV	Vessel collision force
FR	Friction load
IC	Ice load
IM	Vehicular dynamic load allowance
LS	Live load surcharge
PL	Pedestrian live load
SE	Force effect due to settlement
TG	Force effect due to temperature gradient
TU	Force effect due to uniform temperature
WA	Water load and stream pressure
WL	Wind on live load
WS	Wind load on structure

- Choose to apply the same load to all construction stages or vary the load magnitude in each stage.
- Define the load magnitude.

- **Clays:** Here we can define the Clay behavior choosing from the list below.

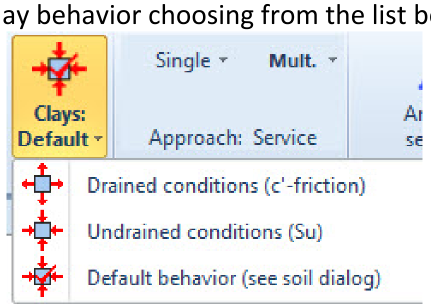


Figure 2.3.7: Clay behavior options.

- **Load combinations:** Here we can select to general a series of load combinations from specified standards such as AASHTO, EC7 etc.

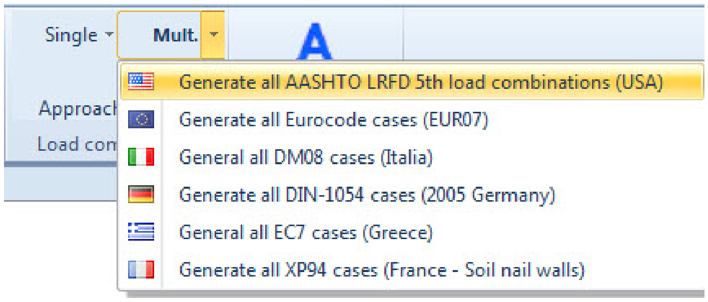
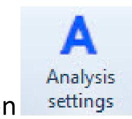


Figure 2.3.8: Load combinations available in HelixPile.

Analysis Settings: By pressing the button 

, the Helical pile analysis settings dialog appears.

General tab: Here we can define the general analysis settings that control how calculations are performed.

Include shaft resistance: If selected, then shaft side resistance will be included. If we opt to include shaft resistance then the following options become available. Please refer to section 5.2 for more information.

Use limiting effective stress: If selected, then a maximum limiting effective stress is used for the cylinder method, for shaft side resistance, and for bearing capacity calculations.

Include tip resistance: If selected, then the tip resistance will be included in the compression bearing capacity calculations. Tip resistance should be included only when the helical shaft is fully plugged.

Use bearing limit: If selected, then the ultimate bearing pressure at each plate is limited according to the formula $q = f\ \gamma\ d\ (N_q - 1)$ where d is the helix diameter. f is commonly taken as 2 according to recommendations by Perko 2009.

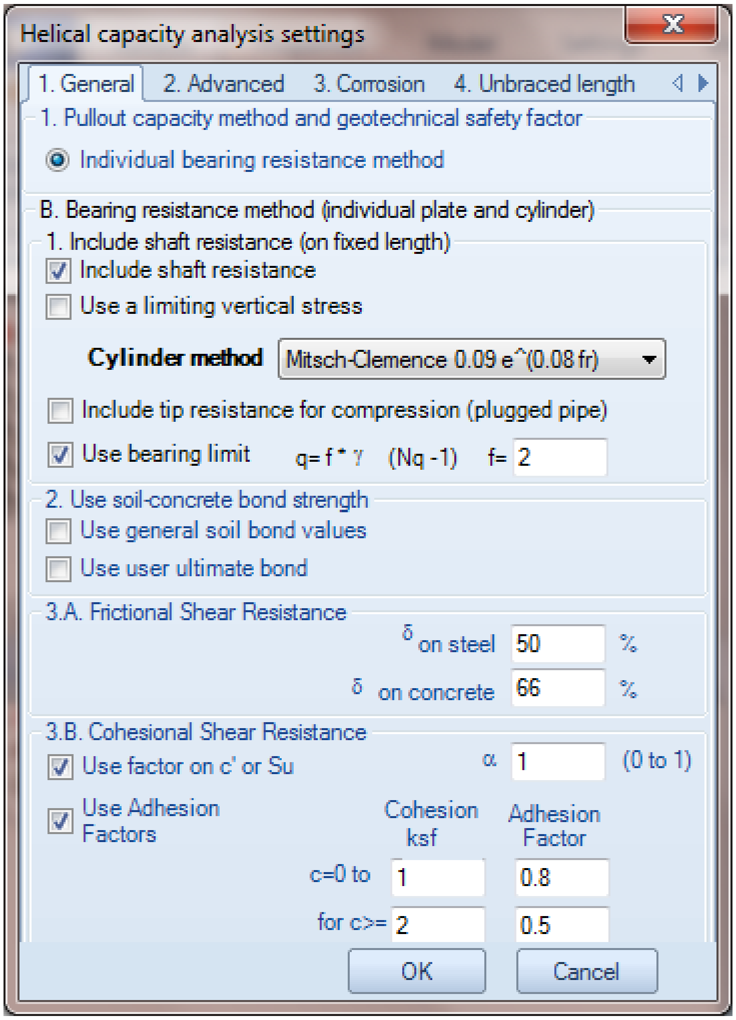


Figure 2.3.9: Helical capacity analysis settings-General tab.

Advanced tab:

- The structural allowable stress factor for determining the structural pile capacity.
- The fixed body and free length colors for the helical piles
- Choose to use custom geotechnical capacity

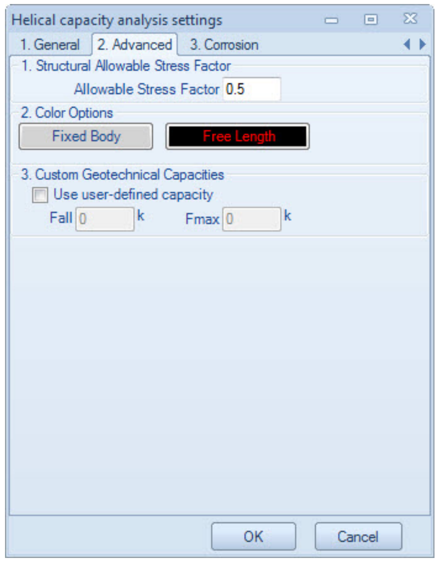


Figure 2.3.9: Helical capacity analysis settings-Advanced tab.

- Corrosion tab: Here we can:
  - Specify the design time (or design life) of the pile.
  - Choose the analysis method. We can choose to use the ICC Method AC355 or the AASHTO2004 Method for moderately corrosive soils.

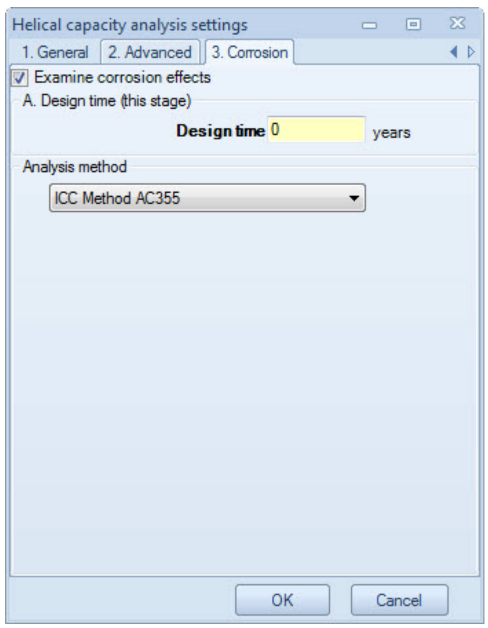


Figure 2.3.10: Helical capacity analysis settings-Corrosion tab.

2.4 Properties menu

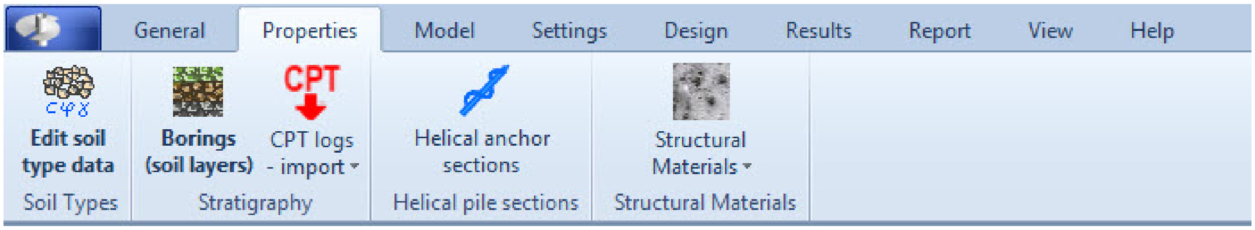


Figure 2.4.1: The Properties tab menu.

- **Edit soil type data:** by pressing the button  , the soil properties form appears. Here we can add, delete and modify available soils by changing their type, the general properties like unit weights, strength parameters and permeability, modify the elastoplastic parameters and modify the bond resistance for tiebacks. A soil can be used in a boring more than one time. A number of estimation tools that help the user estimate values are also included. **Paragraph 3.3 includes all the options that are available in this form**.

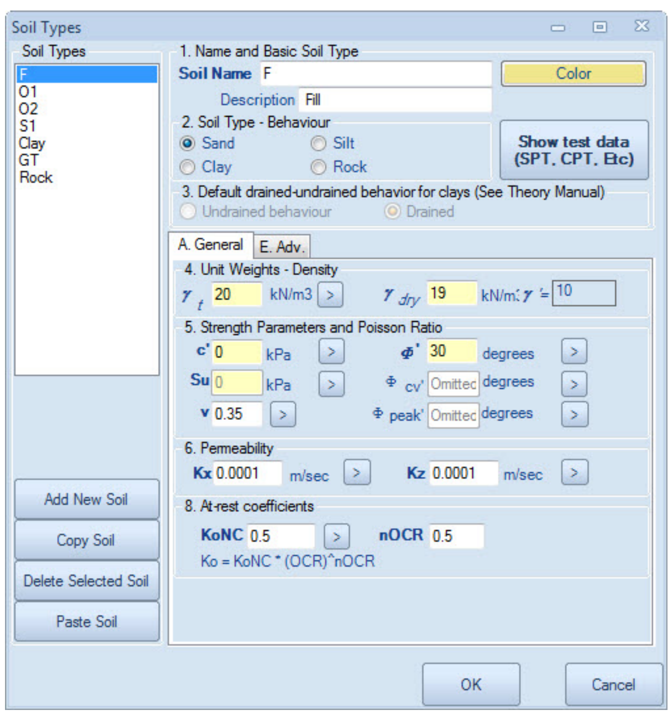


Figure 2.4.2: Edit soil properties dialog.

- **Borings (Soil layers):** by pressing the button 

, the soil layer dialog appears. In this dialog we can edit the borings available for use in the project. In each boring the user can add soil layers. To do this, we can type the new soil layer's elevation, choose the soil type from the list of soil types and define the new layers OCR and Ko. In addition, by clicking on Edit button, we can modify the selected soil's properties **(see paragraph 3.4).** The coordinates X and Y refer to the plan location of the boring and do not affect analysis results.

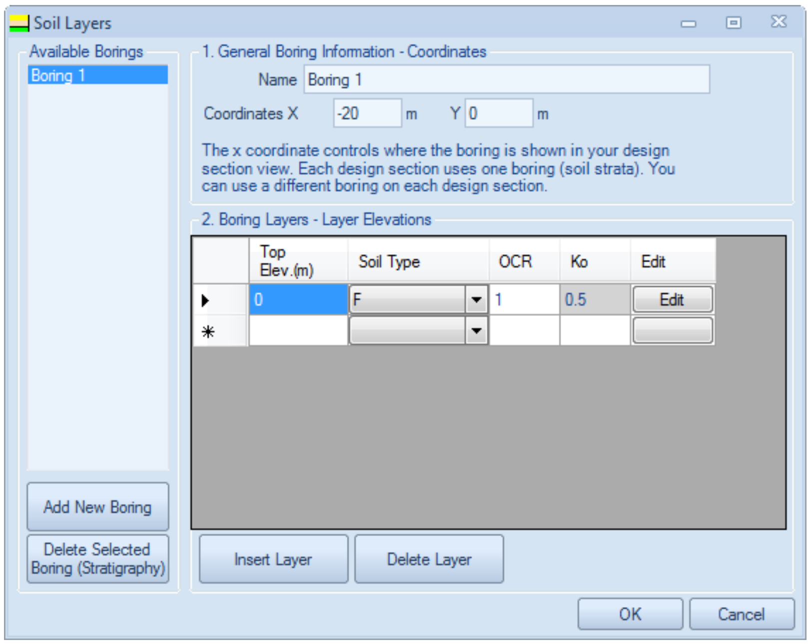
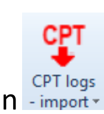


Figure 2.4.3: Edit soil layers dialog.

- **CPT logs:** by pressing the button 

, we can add borings and soils by using a CPT test results file as performed by Geologismiki CPT. The options of Figure 2.4.4. are available. By choosing a CPT log input file, the following dialog appears:

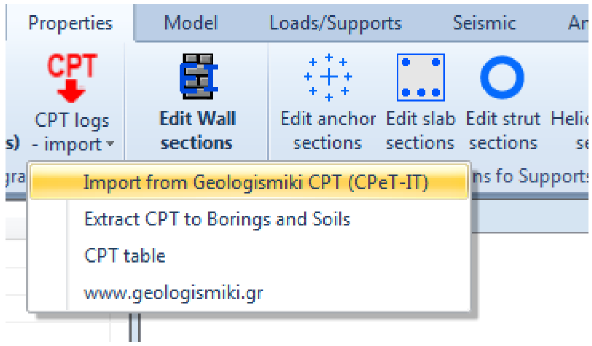


Figure 2.4.4: Available options for CPT logs.

The following options are available:

Import from Geologismiki CPT	Select a CPT file to import
Extract CPT to Borings and soils	Choose to add the soils from CPT log to the model's soils and borings databases
CPT table	This opens the CPT dialog
www.geologismiki.gr	This leads to the site of Geologismiki

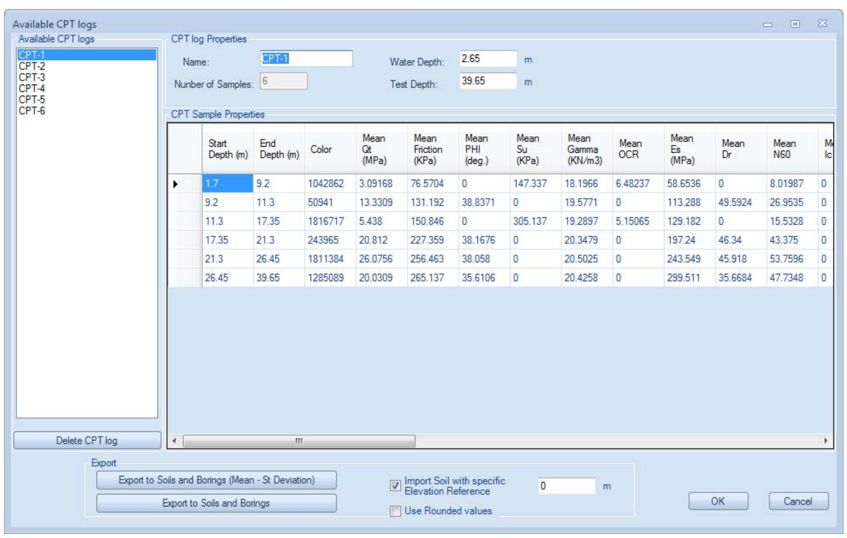
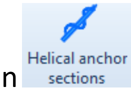


Figure 2.4.5: Available CPT logs dialog.

In this dialog we can export the CPT test borings and soils to the program's database.

- **Edit helical anchor sections:** By pressing the button  we can edit the structural and geotechnical properties of the helical anchor sections (can be used in tiebacks). **The properties that exist on this form and can be modified are described in paragraph 3.5**.

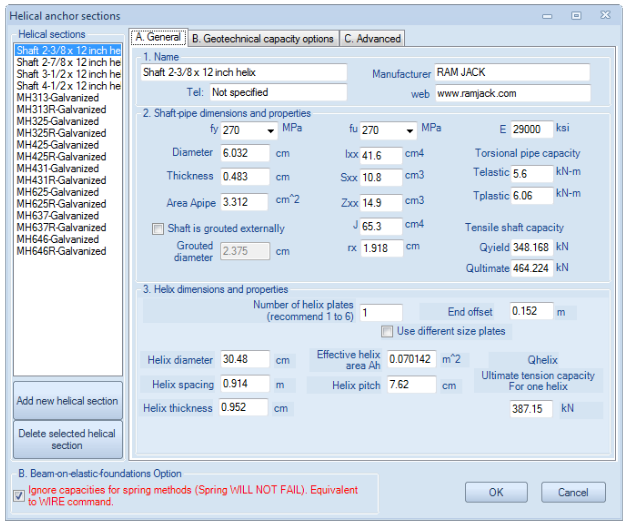


Figure 2.4.6: Edit helical anchor sections dialog.

- **Structural materials:** In this area we can edit the structural material properties.

  The following options are available (Figure 2.4.7):

Concrete
Steel

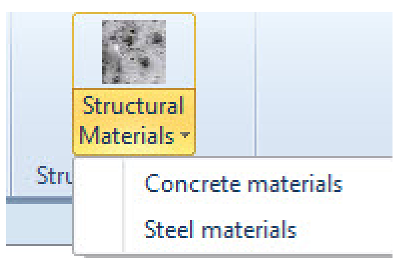


Figure 2.5.9: Structural material options.

- **Edit steel properties:** By pressing the Steel Materials we can edit the structural steel properties. We can import already available materials from the “Import standard steel materials” box.

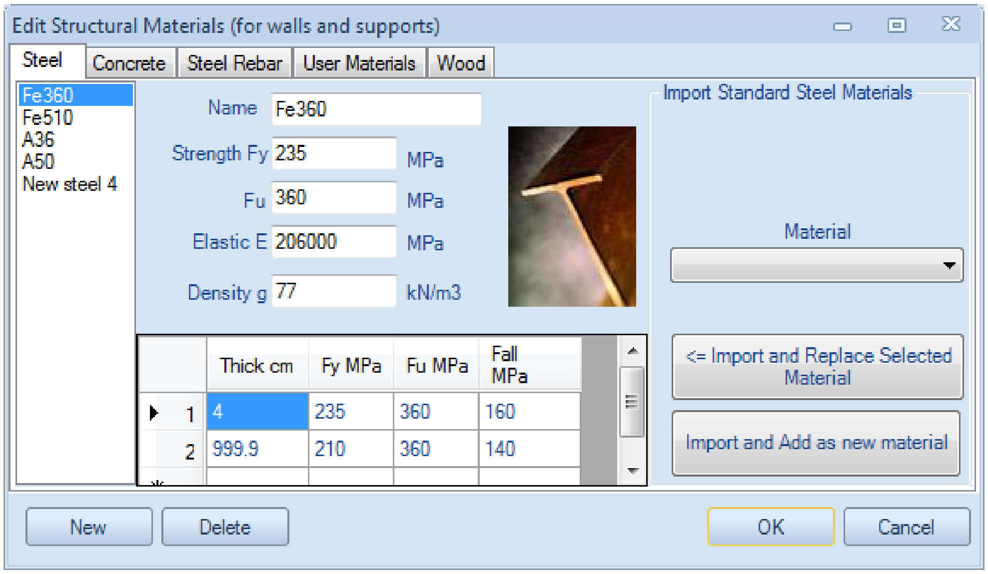


Figure 2.4.10: Edit structural steel properties dialog.

In this form we can define the following properties:

The steel name
The yield strength Fy
The ultimate strength Fu
The modulus of elasticity E
The density g
The steel material used
Import and replace selected material
Import and add as a new material

- **Edit concrete properties:** By pressing the Concrete Materials we can edit the concrete properties. We can import already available materials from the "Import standard concrete materials" box.

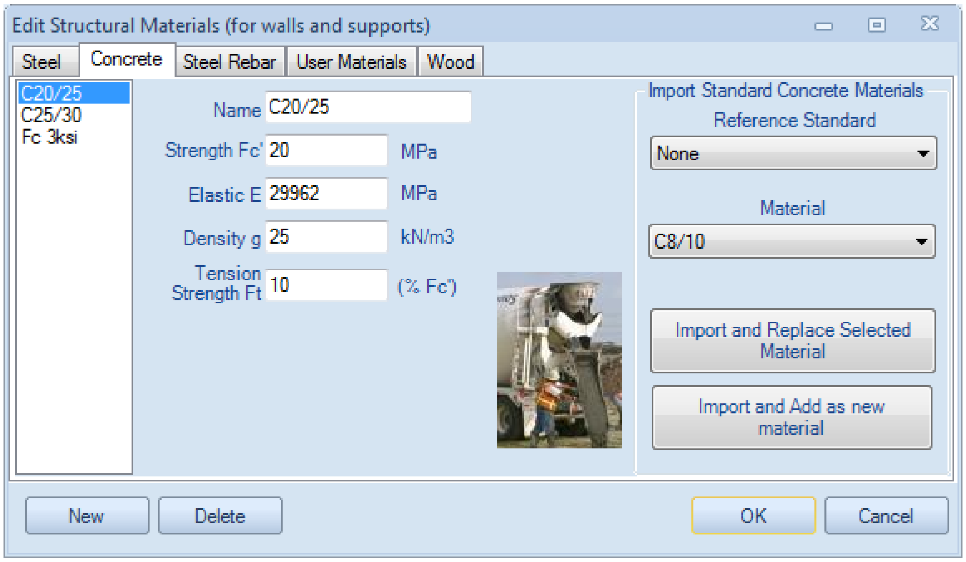


Figure 2.4.11: Edit concrete properties dialog.

In this form we can define the following properties:

The steel name
The concrete strength Fc
The tension strength Ft (% of compressive strength)
The modulus of elasticity E
The density g
The standard concrete material reference standard
The concrete material
Import and replace selected material
Import and add as a new material

2.5 Model menu

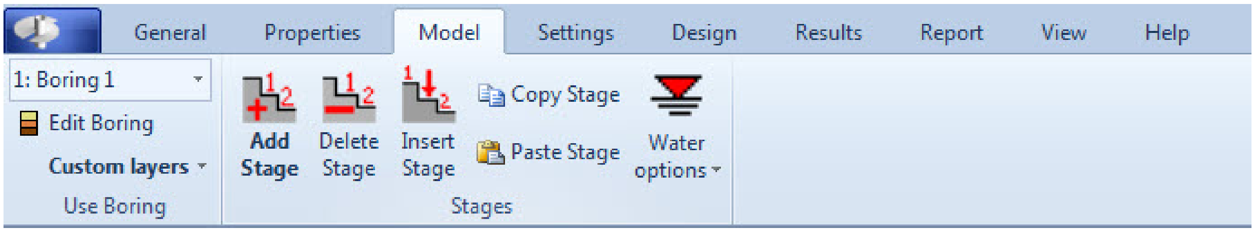


Figure 2.5.1: The Model tab menu.

- **Custom layers:** by pressing the button 

, we can choose to use the Custom layer mode and use non parallel soil layers. In this mode, a model will not use a borehole to define soil layers. Instead, the user can define arbitrary layer lines from left to right and create non-horizontal soil layer conditions.

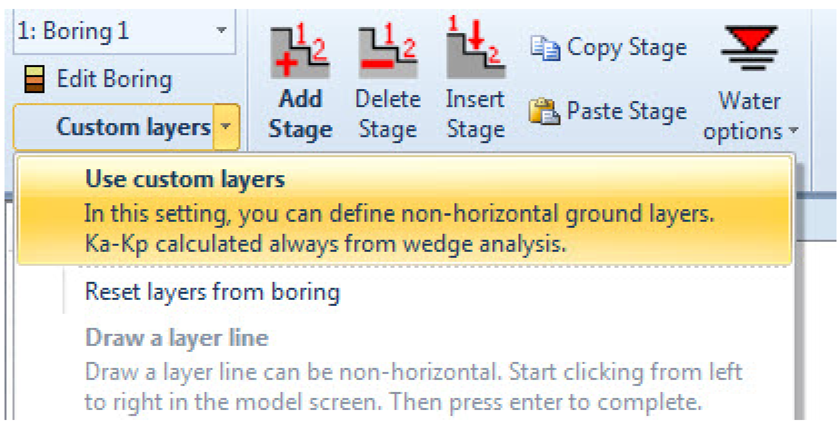
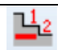


Figure 2.5.2: Custom layers mode.

- The option Use custom layers switches on the custom layer mode.
- The reset layers from boring option, resets all custom layer lines to horizontal using the boring applicable for the current design section.
- The draw layer line tool enables the user to draw a layer line by clicking in the model (left to right). Press enter to complete.

- **Stages:** In this area we can add, delete, insert or copy a construction stage.

Icon	Description
	Add a new construction stage
	Deletes the current construction stage
	Insert a construction stage after the current stage
Copy Stage	Copy selected construction stage
Paste Stage	Paste construction stage

By clicking on the button  , the Ground water table dialog shows up.

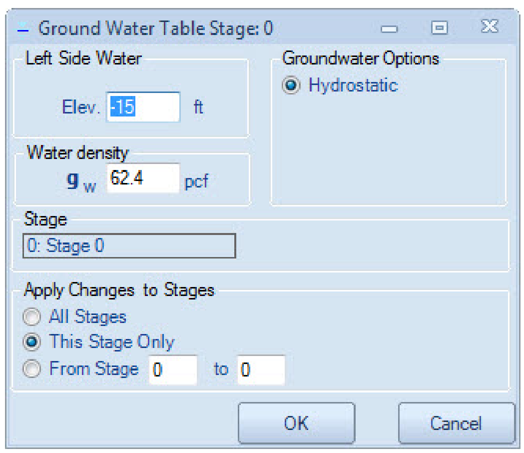


Figure 2.5.3: Ground water table.

The following table presents the options that are included in the ground water table dialog.

Define the general water elevation
Define the water density γ_w

2.6 Settings menu

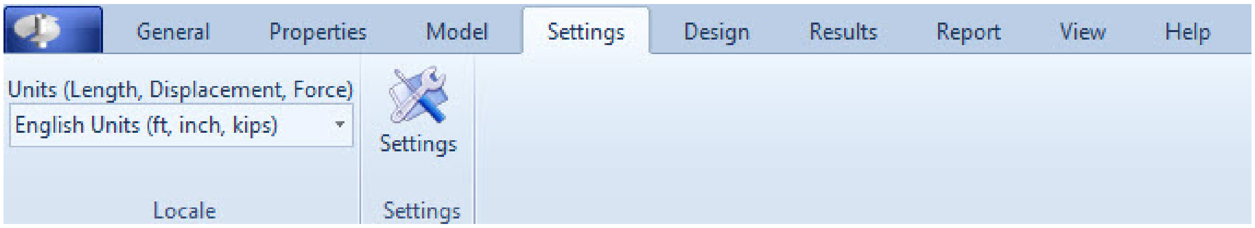


Figure 2.6.1: The Settings tab menu.

- **Locale:** here we can define the units that will be used in this model.
- **Settings:** by pressing the button Settings, the Default Settings dialog appears.

  ➢ General tab: In this tab we can define the default units, company and engineer name and the Auto save directory.

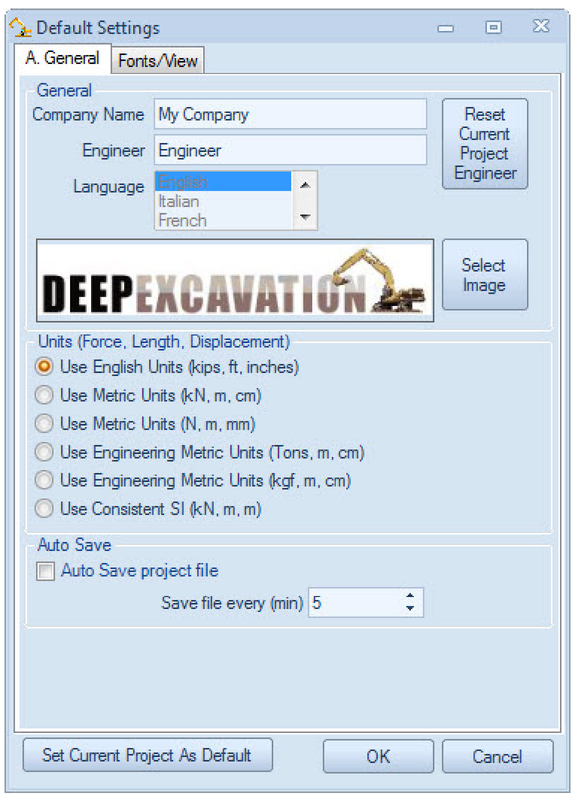


Figure 2.6.2: Settings – General Tab.

➢ Fonts/View tab: In this tab we can define the fonts and some other viewing options.

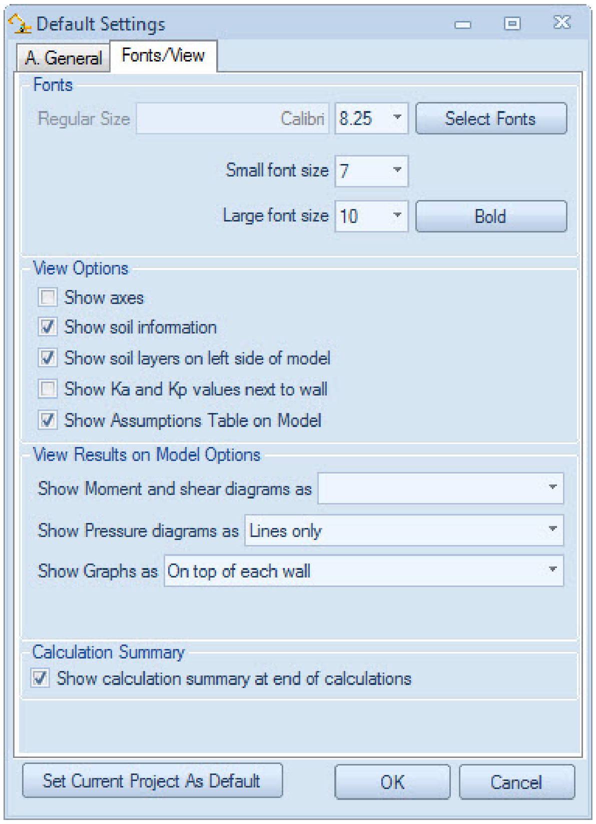


Figure 2.6.3: Settings – Fonts/View Tab.

The available view options are:

- Show axes.
- Show soil information.
- Show soil layers on left side of model.
- Show Ka and Kp values next to the wall.
- Show assumptions table on model.

Furthermore, here we can define some view options regarding the result presentation.

2.7 Design menu

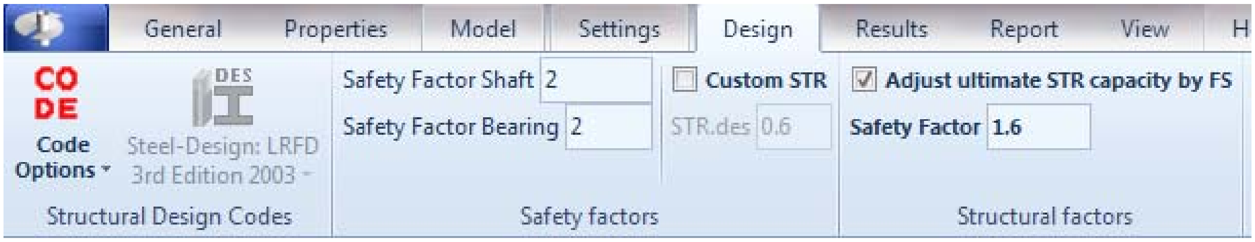


Figure 2.7.1: The Design tab menu.

- **Code options:** By clicking on the button , we can define which structural code's settings to apply in analysis. These code settings control structural codes and other options.

Figure 2.7.2: Code options.

The following options are available:

Use Eurocode 2, 3 settings	Apply Eurocode settings to the design
Use US allowable settings	Apply US allowable settings to the design
Use US LRFD settings	Apply US LRFD settings to the design
Use AASHTO (US) LRFD settings	Apply AASHTO LRFD settings to the design
Italian DM08 Settings	Apply Italian DM08 settings to the design

- **Safety factors:** Here we can define several safety factors to be used in the design. We can define the Shaft FS, the bearing capacity FS, as well as a custom structural FS.

- **Structural factors:** Here we can define load factors that are applied when an ultimate steel code is used for buckling. Please refer to section 5.4 for more information.

2.8 Results menu

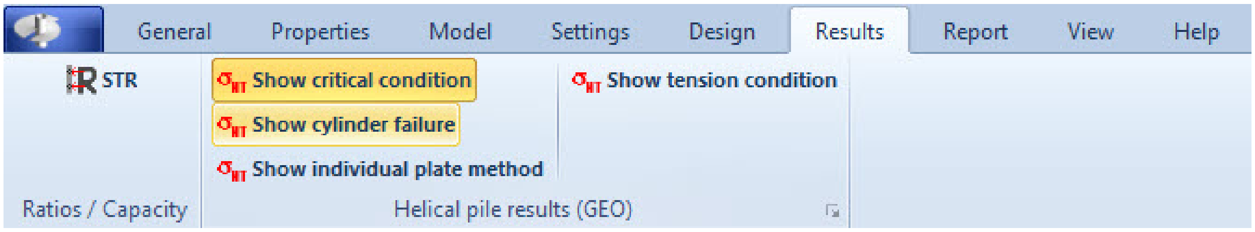


Figure 2.8.1: The Results tab menu.

This tab contains a list of results that can be either viewed on the model or presented in diagrams or tables. Results can be presented when the analysis has been completed.

The following options are provided:

- Show the structural rations on screen.
- Show the critical condition results on screen
- Show the cylinder failure results on screen
- Show the individual plate results on screen
- Show the results for tension condition on screen

2.9 Report menu

From the Report tab we can control options for viewing reports in pdf or word formats as well as see summary tables of all calculations.

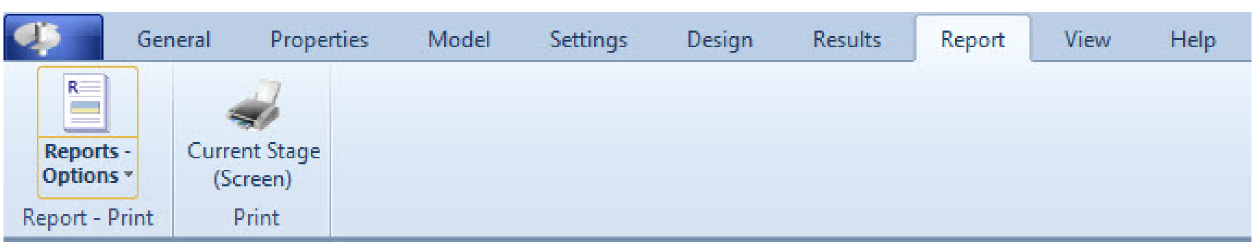
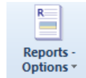


Figure 2.9.1: The Reports tab menu.

Option to create a quick report
Option to create a quick report and include slope stability
Option to create a only stage graphs report
Option to create a typical report

- **Report - print:** By pressing the button 

, the Reports dialog appears. In this dialog we can choose what parts of calculations and results we wants to be included in the reports and the type of file to be exported.

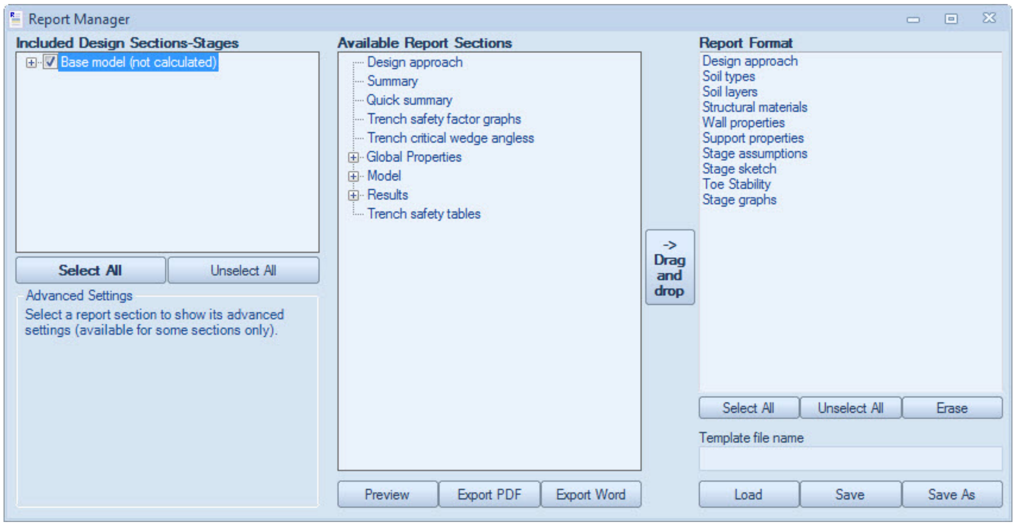


Figure 2.9.2: The Report dialog.

2.10 View menu

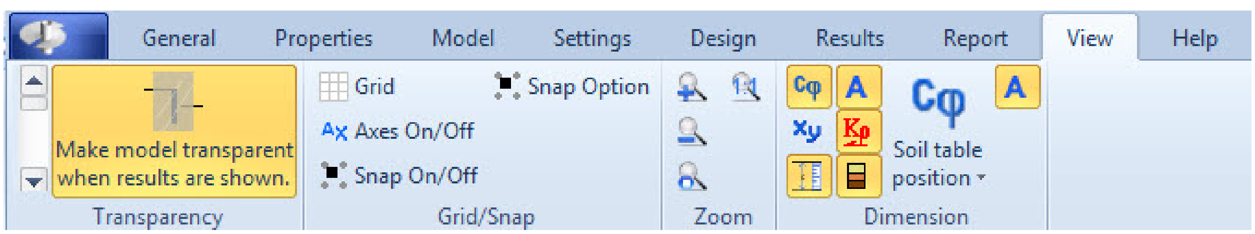
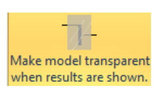
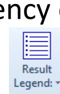


Figure 2.10.1: The View tab menu.

- **Transparency:** By pressing the button 

we can make the model transparent when results are shown. The transparency can be adjusted from the vertical bar.

- **Result legend:** By pressing the button 

we can turn the result legend on or off.

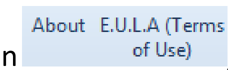
- **Grid/snap:** By pressing the button 

we can change the view options of the snap and axis or show a grid.

- **Zoom and Dimension:** These icons are explained in Chapter 2.1.1.

2.11 Help menu

Figure 2.11.1: The Help tab menu.

- **About and terms of use:** By pressing the button 

, the user can read the terms of use of HelixPile.

Chapter 3: Data Entry

3.1 Data entry: General

HelixPile is a user-friendly software program and includes powerful features and versatile options. In HelixPile we can work with many design sections of an excavation. In a sense, a design section is a design scenario. This way, multiple conditions can be examined simultaneously. The main interface is shown in Figure 2.1.1. The general philosophy in creating a model in HelixPile is:

1) Specify the global coordinates.

2) Specify the soil types and properties.

3) Specify the layers and stratigraphy.

4) Create a generalized water table.

5) Specify the pile properties (pile depth, pile x-coordinate, pile section).

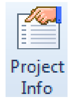
6) Specify different stages

7) Specify HelixPile load combination.

8) Analyze the project.

This Chapter describes the data that should be entered by the user in order to create a proper model.

3.2 Data entry: Project information

By clicking on the button 

, the Project Information dialog appears (Figure 3.2.1). In this dialog we can specify the Project Name, file number (or job number) and the name of the engineer preparing the analysis.

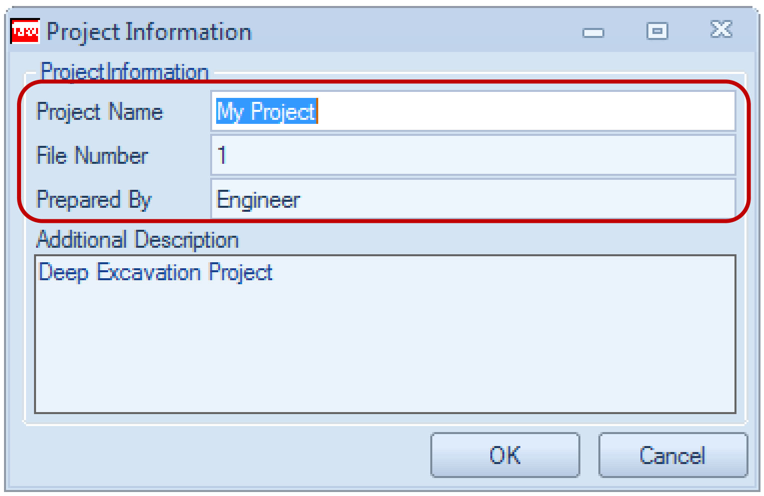


Figure 3.2.1: Project information dialog.

3.3 Data entry: Soil Data

By pressing the Edit soil type data button of the Properties tab, the Soil Types dialog appears. Here the user can create as many soil types as needed and define their properties. First the user should select to add a new soil type, or choose one from the list in order to modify its properties (Figure 3.3.1).

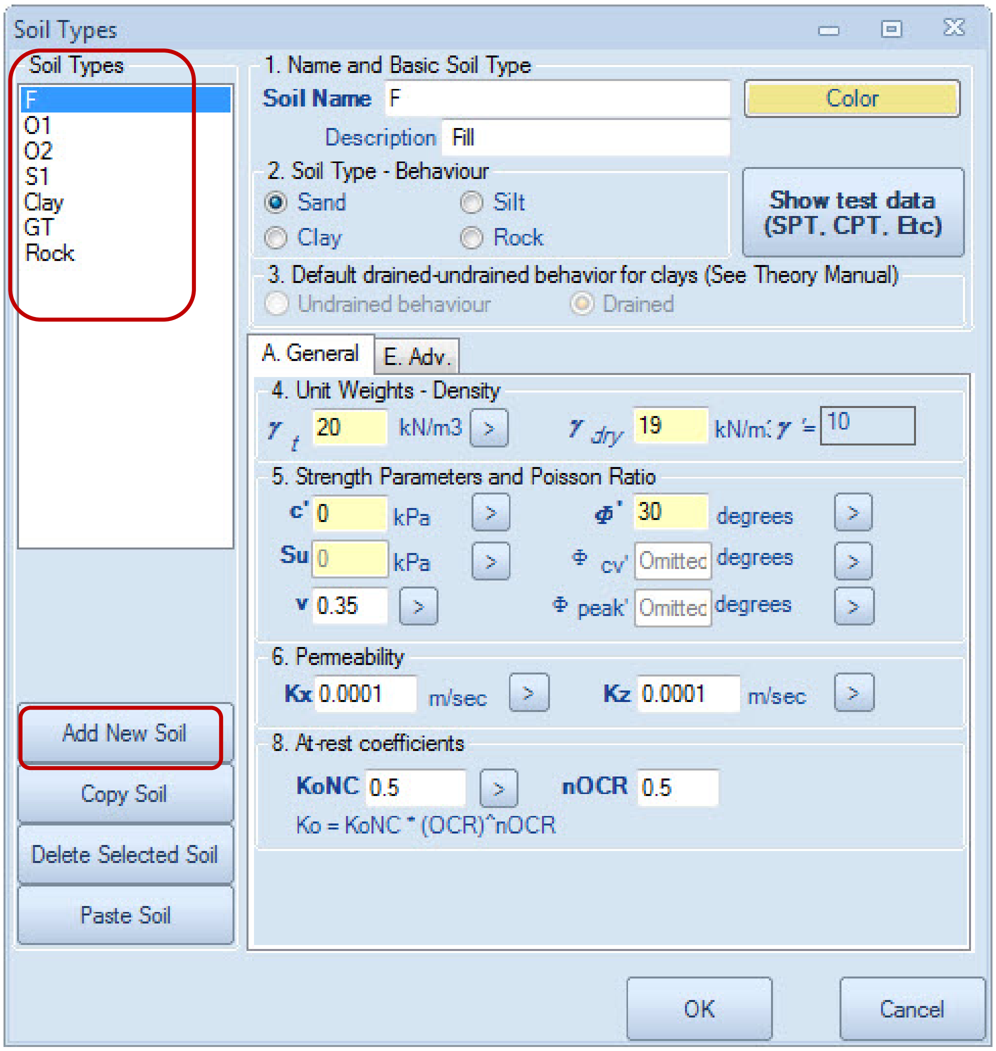


Figure 3.3.1: Add a new soil or select a soil to modify.

We can change the basic soil information such as soil name, preview color and soil type. The available soil types are Sand, Clay, Silt and Rock. If the soil is clay, a drained or undrained behavior of the clay can be defined at this point. All these details can be modified in the area presented in Figure 3.4.2. Next, the user can modify the general soil properties in the area marked in Figure 3.4.3. The basic properties are described in the table below.

Symbol	**Description**
γ_t	Total unit weight of soil (used below the water table)
γ_{dry}	Dry unit weight of soil (used above the water table)
c'	Effective soil cohesion
Su	Undrained shear strength (used for clays when undrained modeling is selected). In the non-linear analysis this is used as an upper limit strength
v	Poisson's ratio (used for loads calculated with theory of elasticity)
Φ'	Effective soil friction angle
$\Phi_{cv'}$	Constant volume effective shearing soil friction angle used in the non-linear analysis for clays
$\Phi_{peak'}$	Peak effective soil friction angle used in the non-linear analysis for clays
Kx	Soil permeability at horizontal direction
Kz	Soil permeability at vertical direction
KoNC	Coefficient of at-rest lateral earth pressures for normally consolidated conditions
nOCR	Exponent for calculating Ko with Ko=KoNC*[(OCR)^(nOCR)]

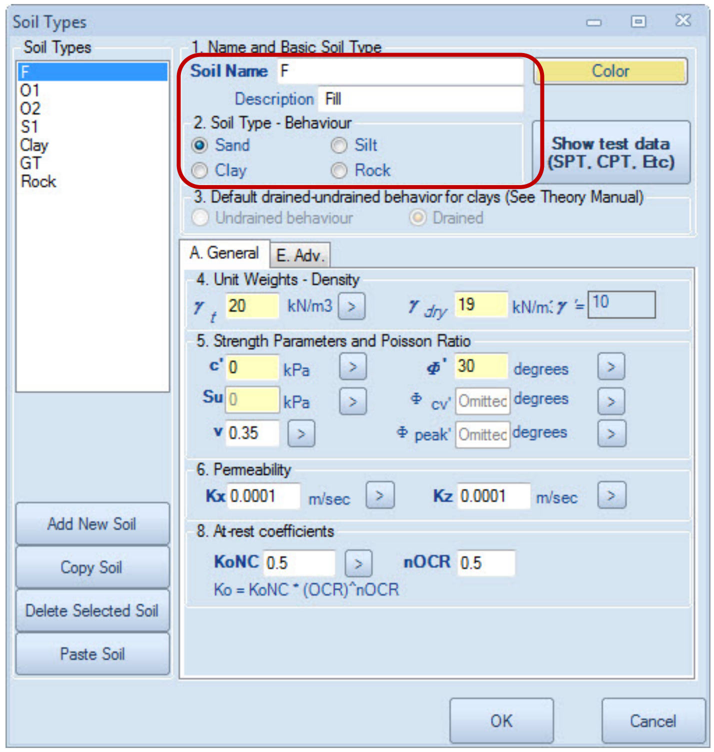


Figure 3.3.2: Define basic soil information.

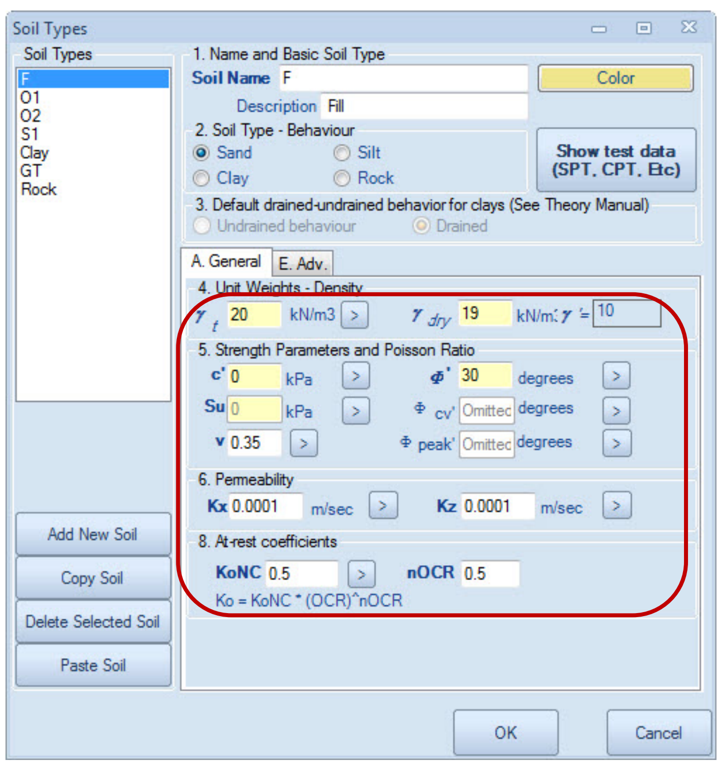


Figure 3.3.3: Define main soil data.

If the user presses the Show Test Data button the dialog expands to the right. Here are available tools for estimating main soil data properties from in-situ tests. Data for standard penetration tests, cone penetrometer tests and pressuremeter tests are included (Figures 3.3.4 and 3.3.5).

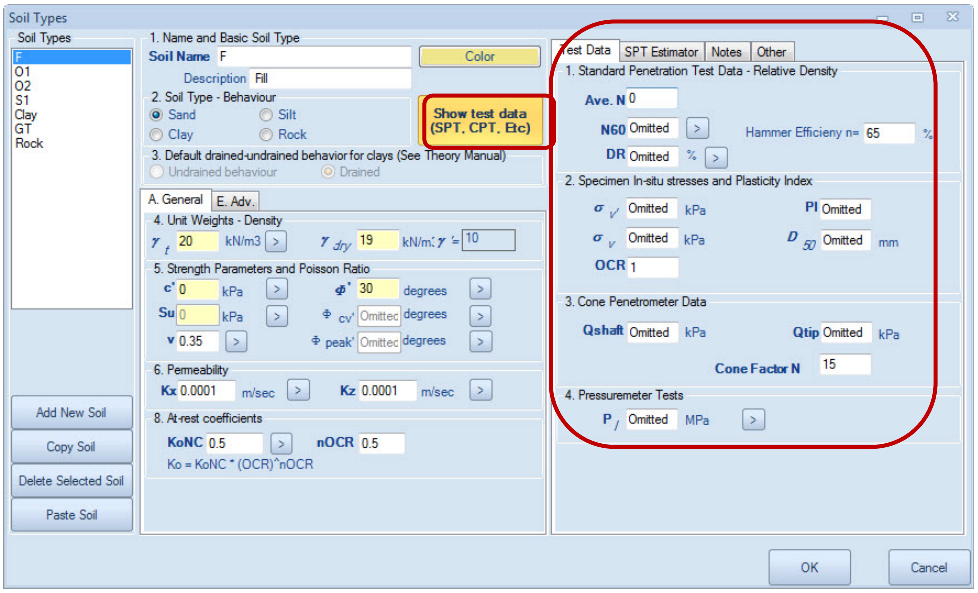


Figure 3.3.4: Test Data.

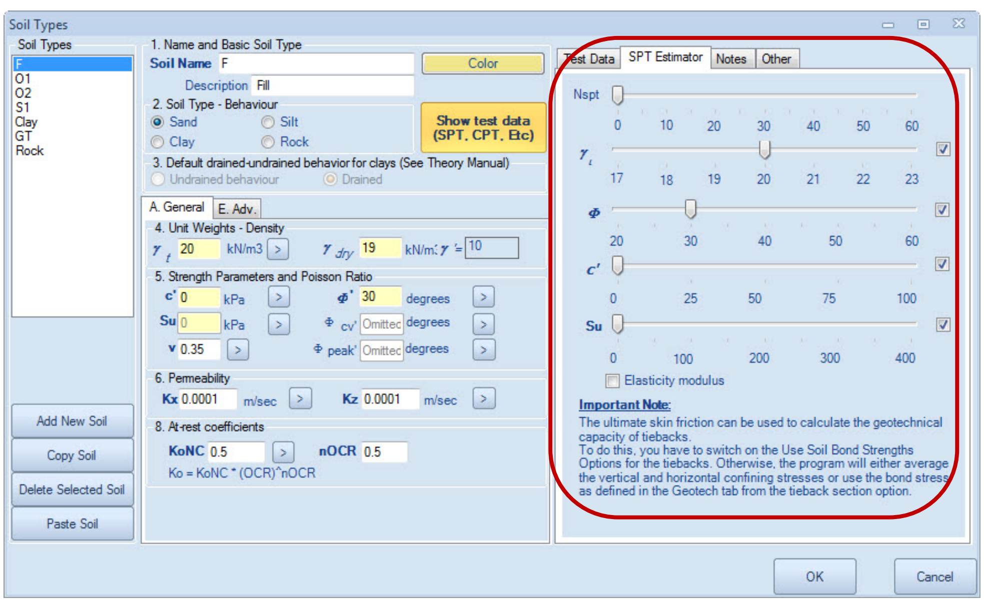
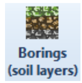


Figure 3.3.5: SPT Estimator.

In addition, next to the main data there is the symbol . This symbol opens a list of tools that can help the user estimate the soil data values according to published literature.

3.4 Data entry: Soil Layers

By pressing the Borings button  of the Properties tab, the Soil Layers dialog appears. Here we add or remove soil layers, specify their top elevation and the soil type to be used. In addition, we can define the exact position of the boring on the screen. This dialog also appears if the user double-clicks on the boring, or if he selects it from the tree view. All these are presented in Figure 3.4.1. The OCR (over consolidation ratio) can be defined herein. The user can include as many borings as desired. Each independent design section can include a different boring.

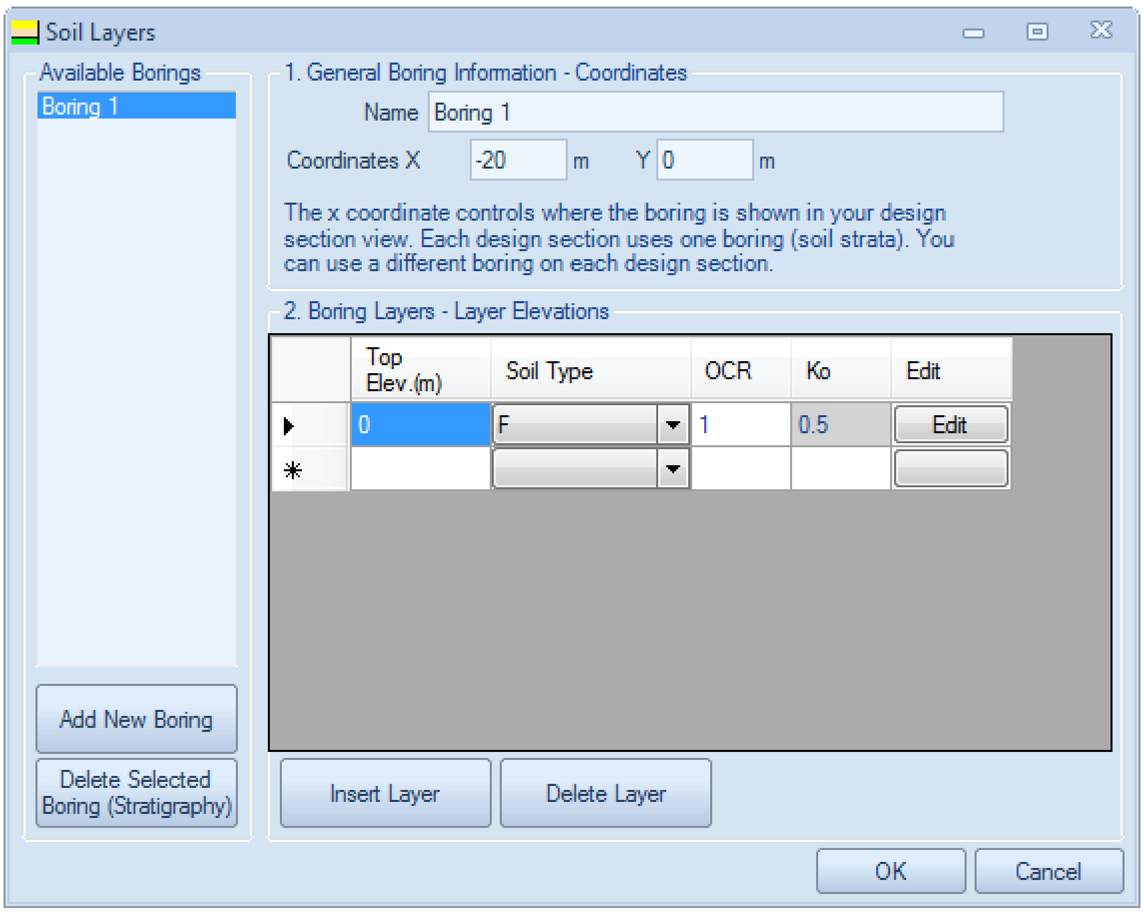


Figure 3.4.1: The soil layers dialog.

3.5 Data entry: Helical Piles

From the Helical Anchors dialog (Figures 3.5.1 and 3.5.2) the user can select an anchor from the existing database of anchors or add some sections to the database. These anchors can use in the project. The General tab contains basic structural information. The Geotechnical capacity tab contains options for calculating the geotechnical tieback capacity. The properties included in this dialog are presented and described in the table below.

HelixPile 2012 has already helical sections from Magnum and Ramjack incorporated (Figure 3.5.1).

Symbol/Option	Description
Fy	Tensile Yield Strength of anchor
Fu	Tensile Ultimate Strength of anchor
Diameter	Anchor diameter
Thickness	Anchor thickness
Ixx	Moment of inertia
Sxx	Elastic section modulus
Zxx	Plastic section modulus
Telastic	Torsional elastic pipe capacity
Tplastic	Torsional plastic pipe capacity
E	Modulus of elasticity
Apipe	Area of the pipe of the anchor
Qyield	Tensile yield shaft capacity
Qultimate	Tensile ultimate shaft capacity
Helix diameter	The diameter of the helical plate
Helix spacing	The spacing between the helical plates
Helix thickness	The thickness of the helical plate
Effective helix area	The effective area of the helical plate
Helix pitch	The helical plate inclination
Qhelix	Ultimate tension capacity for one helical plate
FS	Factor of safety
σ' vmax	Limiting vertical stress

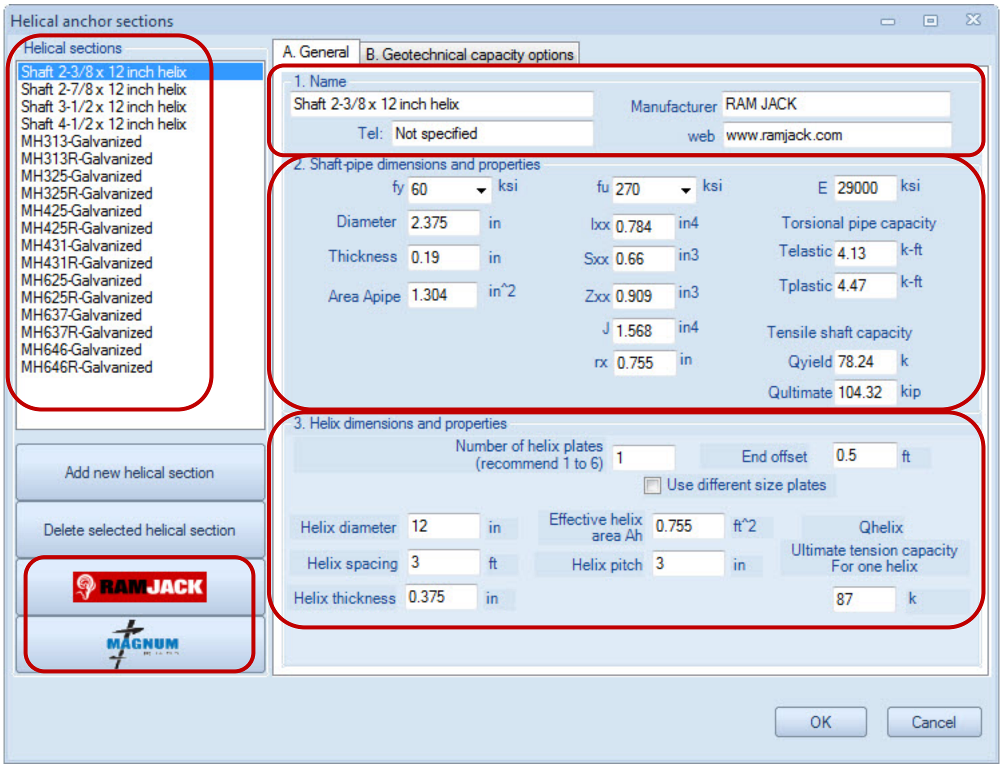


Figure 3.5.1: Helical anchor sections dialog-General tab.

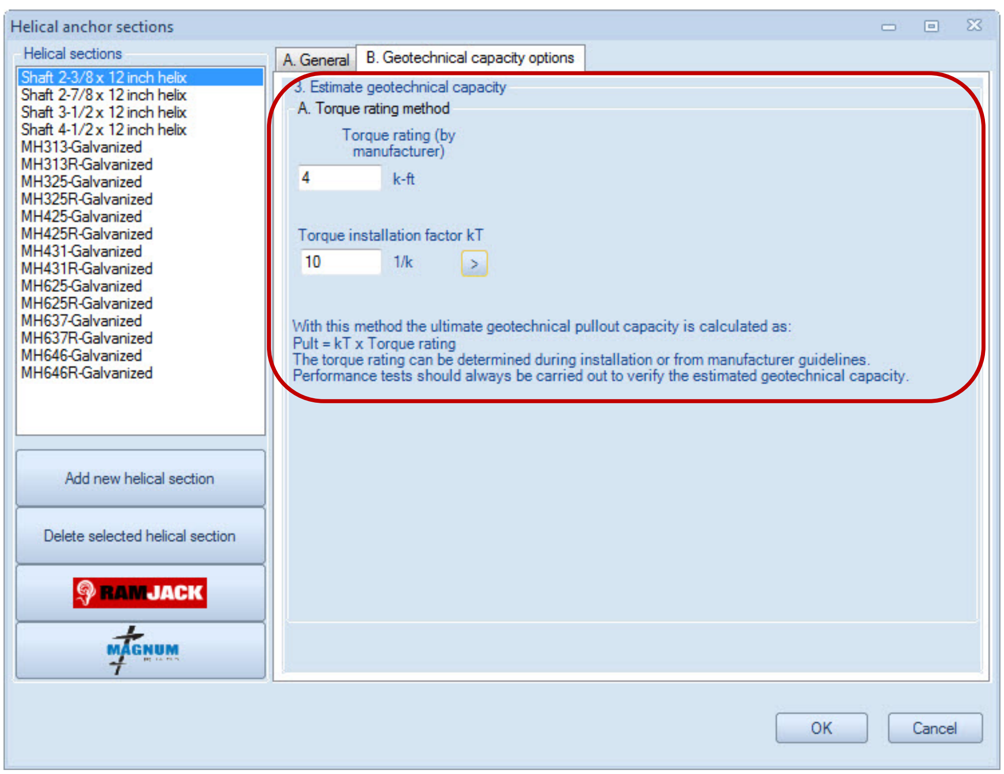
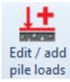


Figure 3.5.2: Helical anchor sections dialog-Geotechnical tab.

Chapter 4: Modifying Models & Viewing Results

4.1 Adding Pile Loads

Line loads in HelixPile can be added for each construction stage. The user has to click on button 

in the General tab of HelixPile to add or edit the loads

Example: Adding Loads

Step 1: Click on the button 

(Figure 4.1.1)
Step 2: Choose to add new load (Figure 4.1.2)
Step 3: Modify the load type and magnitude (Figure 4.1.3)
Step 4: Choose whether to apply this load to all stages, or to modify it for each stage (Figure 4.1.4)

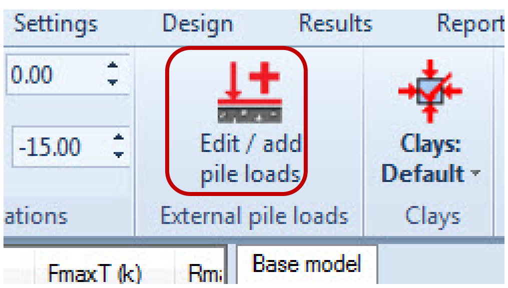


Figure 4.1.1: Add a load tool (step 1).

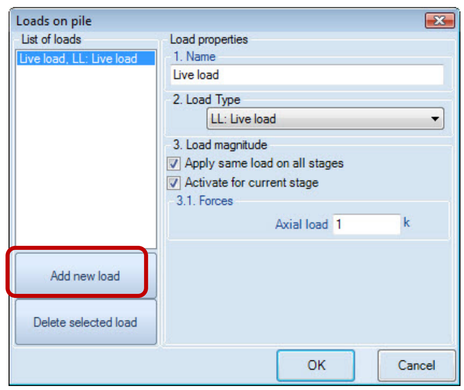


Figure 4.1.2: Add a new load (step 2).

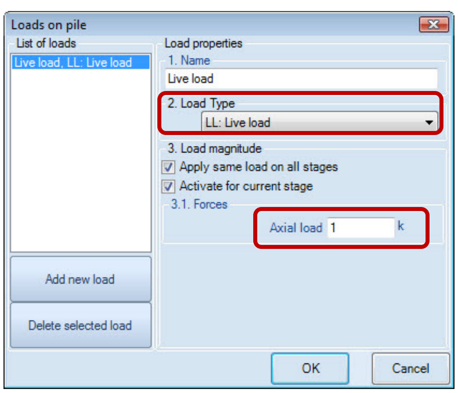


Figure 4.1.3: Define load (step 3).

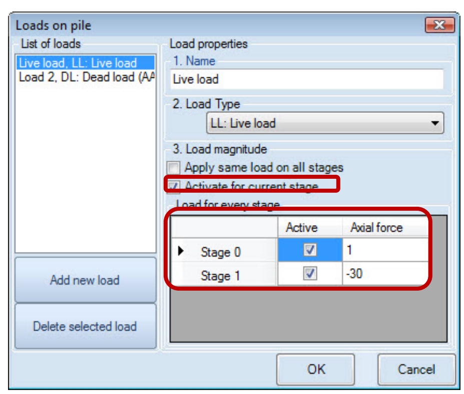


Figure 4.1.4: Change load for each stage (if needed)

4.2 Viewing Results on Main Form

Once a project is analyzed, results can be viewed on screen by selecting one or more of the options provided below:

- Show the structural rations on screen.
- Show the critical condition results on screen
- Show the cylinder failure results on screen
- Show the individual plate results on screen
- Show the results for tension condition on screen

HelixPile can graphically represent results for all analyzed design sections and stages. The following figures show some typical on screen output diagrams and results. Output results can be visible only if the given problem has been analyzed. Feel free to explore the functionality of these toolbars.

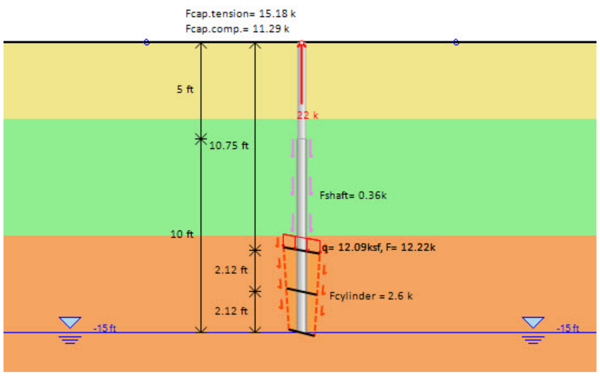


Figure 4.2.1: Critical condition results.

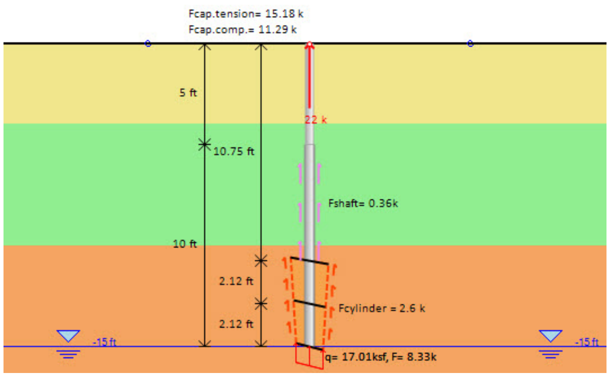


Figure 4.2.2: Cylinder failure results.

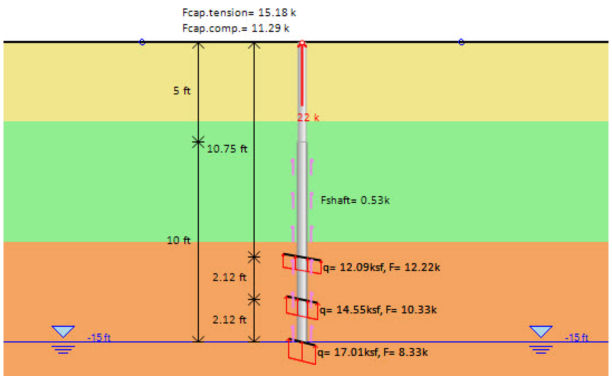


Figure 4.2.3: Individual plate method.

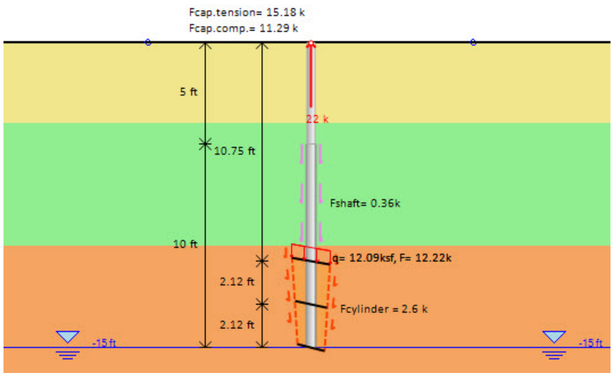


Figure 4.2.4: Tension condition.

4.3 Report Options (Printed Reports)

Once a project is analyzed, full analysis reports can be generated by selecting the Reports – Options option at the Report tab. By selecting this, we can modify the included output sections. On the left side of the dialog, we can select which design sections and stages will be included in the current report (Figure 4.3.1). From the Available Report Sections area, we can select the results and options that shall be included (Figure 4.3.2). We can also drag and drop these items at the Report Format area (Figure 4.3.3). Next, the user can select to see a preview of the report and export it in a word or PDF format at the area indicate in Figure 4.3.3.

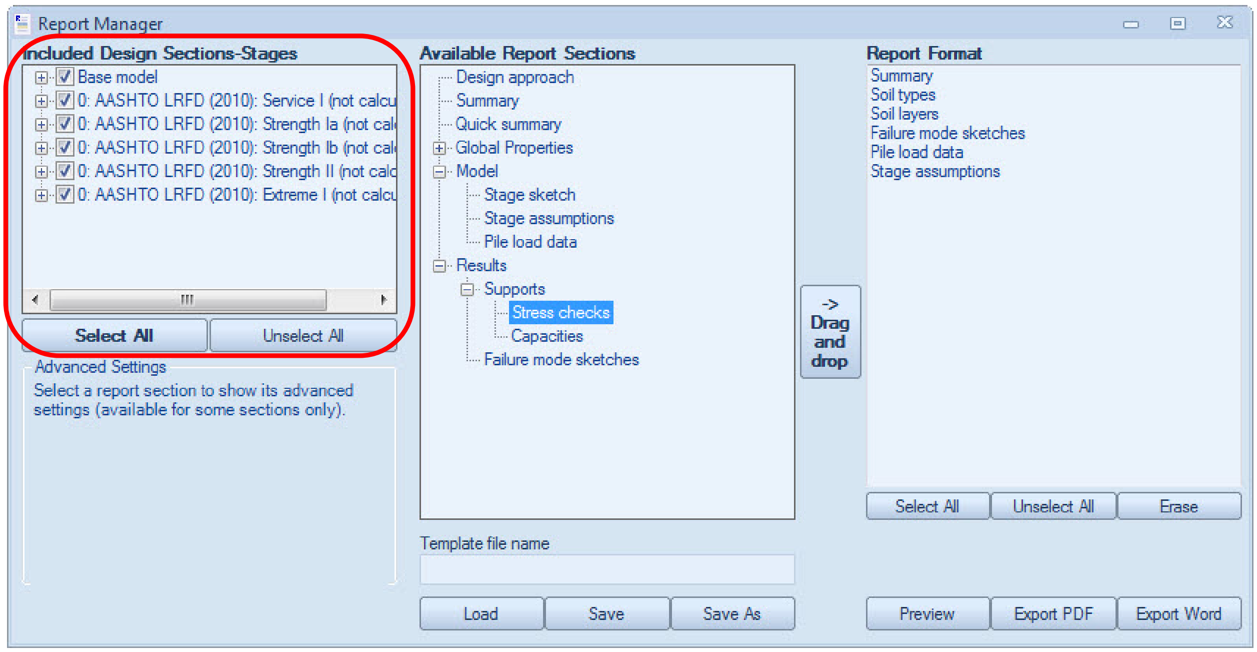


Figure 4.3.1: The included Design Sections area.

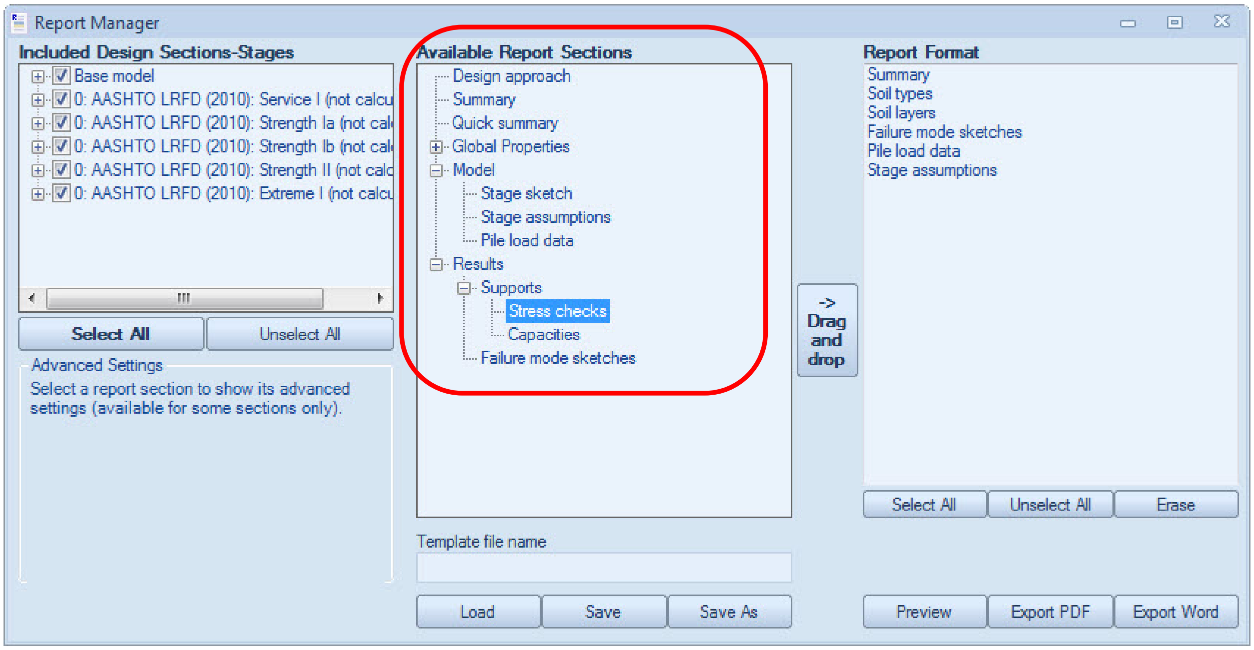


Figure 4.3.2: The Available Report Sections area.

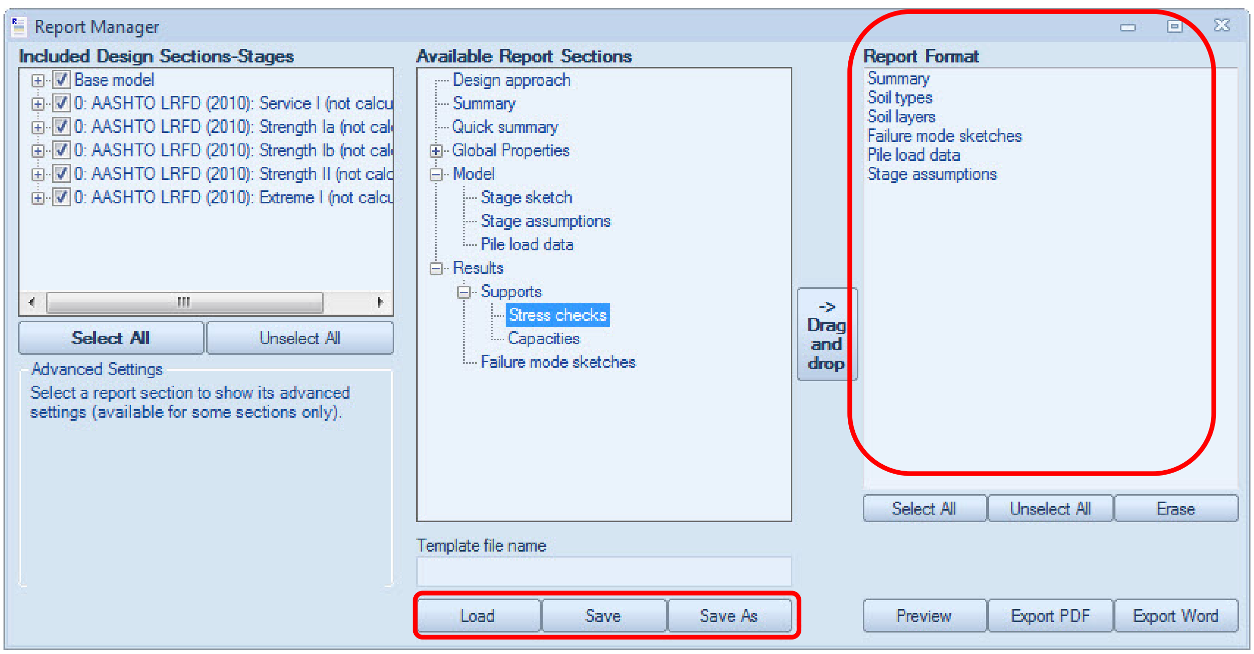
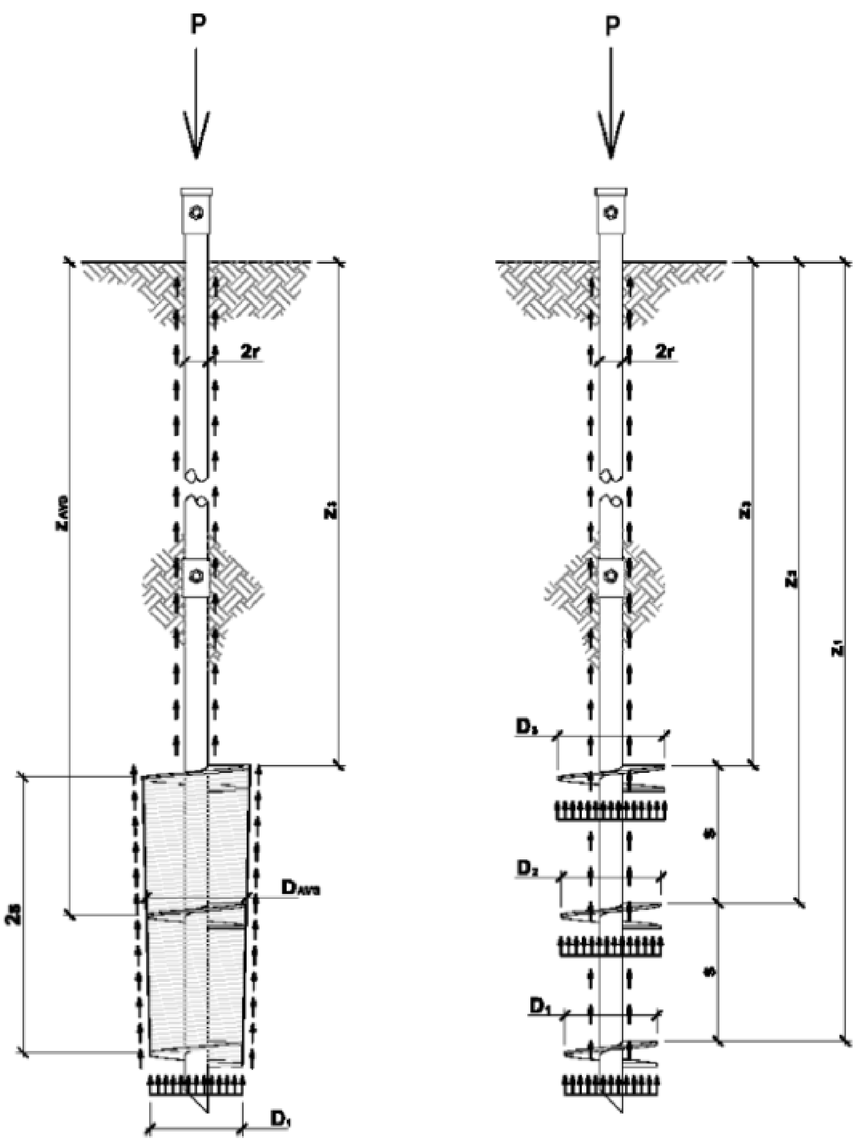


Figure 4.3.3: The Report Format area and the preview and export buttons.

Chapter 5: Theoretical background

5.1 Theoretical background

Helical piles derive their capacity from bearing and side resistance. In general, two geotechnical modes are recognized for helical pile failure: a) Individual plate failure mode, and b) cylinder failure mode, as illustrated in the following figure. If the helix spacing is large enough, then each helix will act independently and the individual bearing capacity failure will control at each plate (provided that the plates has sufficient structural capacity). On the other hand, if the helical plates are spaced close enough then the capacity will be controlled by the bottom plate bearing failure and side resistance along the cylinder bound by the helical plates (for compression).



Cylinder method **Individual plate,**

Figure: Helical pile theoretical failure modes.

The general bearing capacity equation used within the software is:

$$q_{ult} = c\,N_c + \left(N_q - 1\right)\sigma' + 0.5\,\gamma\,D\,N_\gamma$$

Where:

c = Effective cohesion or undrained shear strength

D = Helical plate diameter

γ = Soil unit weight

σ'= Effective vertical stress

The bearing capacity factor N_q according to Vesic 1974 is calculated as

$$N_q = 0.5\,(12\,\varphi\,)^{\varphi/54}$$

The bearing capacity factor N_γ according to Vesic 1974 is calculated as

$$N_y = \left(N_q - 1\right)\tan\,(1.4\,\varphi)$$

Where φ is the effective friction angle in degrees.

For fine-grain soil where φ= 0 degrees, Hansen and Vesic equations yield a N_c equal to 10. However, Skempton (1951) showed both theoretically and experimentally that N_c approaches a constant value of 9 for deep foundations. Most practitioners used Skemption's result for the φ= 0 degrees condition. Under this condition, the second and third terms in bearing capacity equation go to zero because N_q= 1 and N_γ= 0. For this reason, the program assumes a conservative value of N_c = 9 even when the friction angle is greater than 0.

However, use of general bearing capacity equation would result in the calculated ultimate bearing pressure increasing without bound as q increases steadily with depth. In many cases this leads to an overprediction of bearing capacity. It has been proposed that the bearing pressure at the base of a deep foundation reaches a maximum limit at some critical depth (Meyerhof, 1951, 1976). The critical depth has been established for straight shaft piles based on a number of load tests. However, previously published critical depths for other types of deep foundations may not apply to helical piles.

Perko (2009) concluded that in summary, the ultimate bearing pressure for helical piles in coarse-grain soils may be computed using traditional bearing capacity theory by replacing the effective overburden stress, q' with the product of soil unit weight, γ, and two times the average helix diameter, Davg. Within the analysis settings dialog, one can select the Use Bearing Limit option as q= f x γ (N_q -1). Here the default f=2 value is proposed, but this can be changed according to user preference.

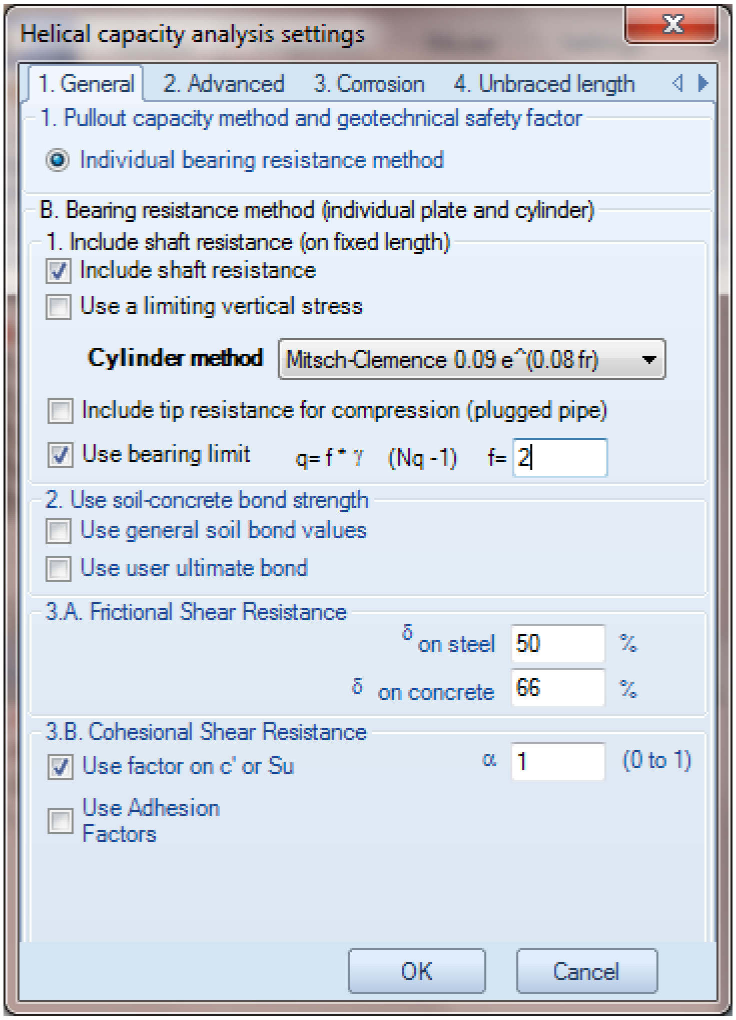


Figure 5.1: Analysis settings for limiting bearing pressure

5.2: Shaft side resistance

While in general shaft side resistance is ignored, in some occasions it might be desirable to incorporate shaft resistance within the calculations. In HelixPile there are two methods of calculating shaft resistance a) Effective stress approach, and b) soil bond values. If the option Use general soil bond values is not selected, then the program will use an effective stress approach for calculating shaft side resistance.

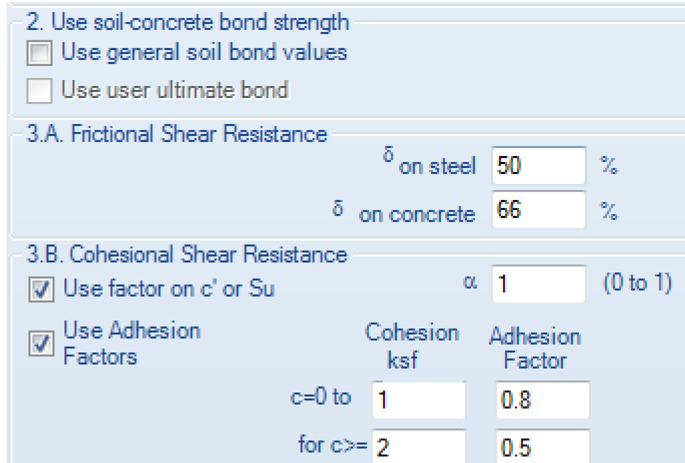


Figure 5.2: Shaft resistance options in analysis settings dialog

a) General soil bond values: Side resistance is calculated from the bond resistance values in the soils type dialog. This condition would be more appropriate for grouted shafts or pressure grouted shafts where the external shaft is encased in concrete.

b) Effective stress approach: In the effective stress approach, the program calculates the average effective vertical and lateral stress along the shaft. Shaft resistance is then determined from:

$$\tau = \tan(\delta\, \phi)\, \sigma'_{ave} + \alpha\, m\, c'$$

Where:

δ = Ratio of shaft to soil friction. Default δ_{steel} value is used. If the helical pile is grouted, program will use $\delta_{concrete}$. Please note that the initial percentages are general estimates and that they should be adjusted if site conditions differ.

ϕ = Effective soil friction angle

σ'_{ave} = Average normal soil stress along the shaft

α = Overall adhesion factor for cohesive component of side stress

c'= Effective cohesion or undrained shear strength for clays in undrained state.

m= Optional factor applied on cohesive side stress that reduces adhesion with tri-linear approach. In figure 5.2, for c<= 1 ksf then m= 0.8, for c>=2ksf m= 0.5 while the program performs a linear interpolation for intermediate values. The initially assumed limits are obtained from experience and general references, but should be adjusted if soil-adhesion behavior differs.

5.3 Cylinder strength method

HelixPile also examines cylinder strength to determine which axial loading condition is more critical. The program subdivides the space between plates into a number of nodes where the side shear strength on the cylinder is integrated from a side resistance of:

$$\tau = \tan(\phi)\, \sigma'_{ave} + c'$$

Where:

δ = Ratio of shaft to soil friction. Default δ_{steel} value is used. If the helical pile is grouted, program will use $\delta_{concrete}$. Please note that the initial percentages are general estimates and that they should be adjusted if site conditions differ.

ϕ = Effective soil friction angle

σ'_{ave} = Average normal soil stress along the shaft

If the plate sizes are different, then the program calculates and includes both the cylinder angle (from the pile axis) as well as the effective diameter along the virtual cylinder. The angle inclination of the cylinder in respect to the pile axis should make little difference in most cases.

5.4 Structural capacity calculations

Initially the design structural capacity of the pile is calculated as:

$$P_{des} = \alpha \cdot P_y$$

Where: Pdes = Design axial capacity

Py= Yield strength of shaft

α= Design stress factor (for allowable design typically taken as 0.5)

α is controlled from the Analysis settings dialog, tab B. Its value is automatically updated when a new structural code is selected from the Design tab.

The program also considers the structural capacity according to the selected structural code standards. This affects the compressive structural capacity when buckling is considered. HelixPile determines which loading condition is controlling in each stage, and reports the respective structural capacity.

The unbraced length below the surface has to be defined by the user depending on soil conditions for each helical pile. The program subsequently tries to determine if the pile sticks

out of the ground and incorporate this length into the effective unbraced height. Last, the effective unbraced length is calculated by multiplying by the unbraced length factor k which accounts for the end conditions of the beam. The initially assumed value is assumed as 1 (for a pinned beam at both ends), while typical values can range from 0.65 to 2 depending on the assumed fixity conditions.

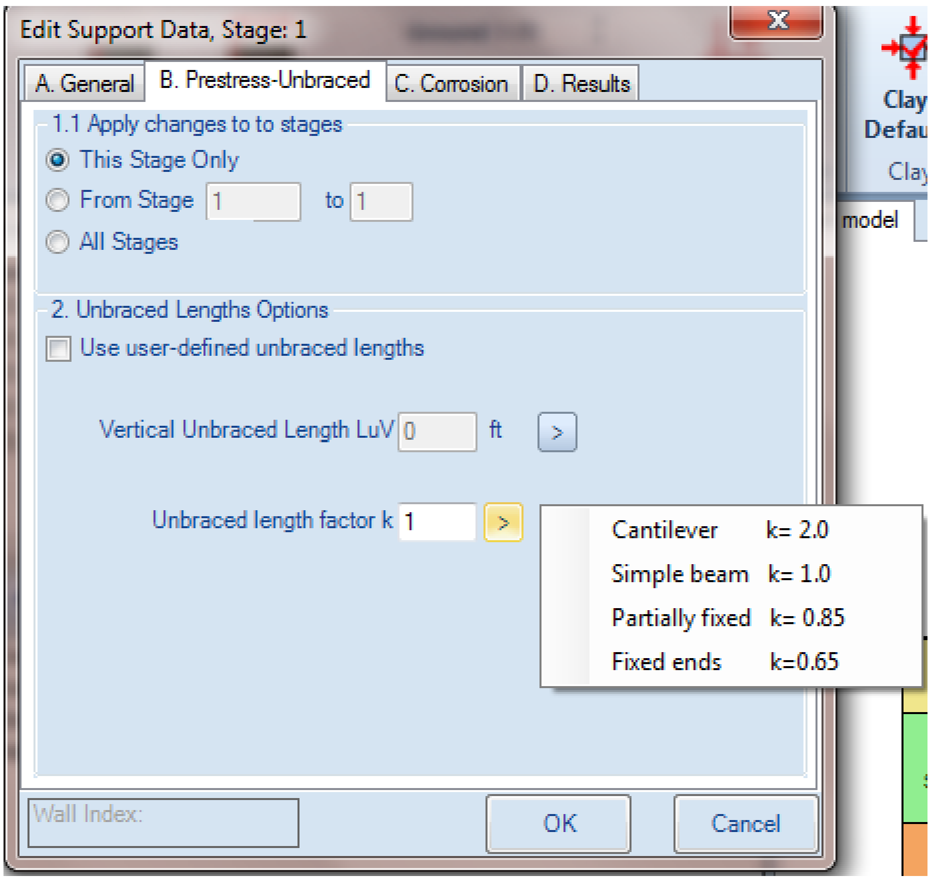


Figure 5.3: Unbraced length factor with standard recommendations

When ultimate structural codes such as AISC LRFD editions are employed, then a designer might have to consider additional safety factors applied to the structural analysis. This will also depend on whether external pile loads are factored or not. For example, if external pile loads are not factored and AISC LRFD is used, then it might be prudent to use a safety factor of 1.6 or greater to factor services loads for the buckling structural analysis according to building code standards. These settings, are initially automatically set when a building code is selected but can be adjusted from the design tab as shown in Figure 5.4. When an overall safety factor is used, the assumptions table will also show that a safety factor is applied by the name of the structural code.

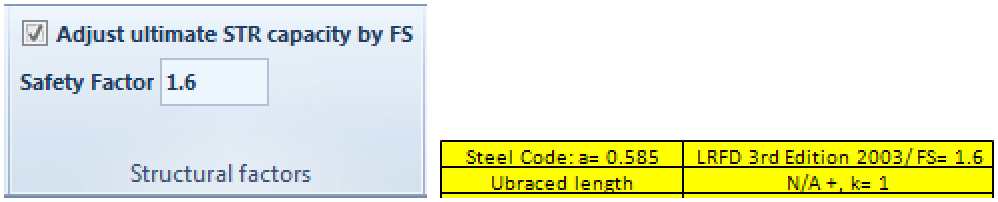


Figure 5.4: Using a safety factor on loads for ultimate structural codes such as AISC LRFD

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